A Business Perspective on Public Regulation

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The Faculty of Economics, Business Administration and Information Technology of the University of Zurich hereby authorizes the printing of this dissertation, without indicating an opinion of the views expressed in the work.

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Preface

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Zurich, August 2013 Simon Wey

Framework Paper

This dissertation consists of three essays that address public regulation from a business perspective.

Essay 1 examines product markets in which state-owned and private firms compete. State-owned firms traditionally play an important role in providing both infrastructure and services in network industries such as telecommunications or energy. Apart from the controversial question whether a state-owned firm should be allowed to compete in a market with private firms, it is not very well understood to what extent investment decisions of private firms are biased. In particular, it is not clear whether state-owned firms will crowd out investments by private firms. This concern is particularly relevant in industries where firms must make large up-front investments to compete in the product market. So far, this concern has been largely ignored in the literature.

We address this question using a model of rivalry between the state-owned and the private firm and provide a formal analysis of the strategic interaction of investment and pricing decisions by the two firms. Investments are regarded as strategic if firms do not only take into consideration their own but also the competitor's profit function. We examine a duopoly model with differentiated products where the firms make demand-enhancing investments. Importantly, the state-owned firm adheres to a "political agenda." The political agenda recognizes that a state-owned firm might be under political pressure from politicians who control it.

We derive the following three key results. First, we employ a reduced-form analysis and characterize the strategic public and private investment based on the taxonomy of Fudenberg and Tirole (1984). They classify investments from two perspectives: whether the private firm regards public investment as substitutes or as complements and on how the state-owned firm assesses the private firm's investment. According to their taxonomy, in three out of four scenarios the profit-maximizing behavior of both firms militates against a crowding out of private investment. Second, we establish two conditions which must be satisfied for the crowding out to occur: (i) the private firm regards investments as strategic substitutes and (ii) the state-owned firm regards private investment as undesirable. Third, we illustrate the derived scenarios with a linear demand example, which reveals that the two conditions for a crowding out critically depend on the economic fundamentals of the industry under study. As an example, we apply our model to the telecommunications industry where "next-generation" fibre-optic networks are being built in many industrialized countries. In Switzerland, for instance, there is anecdotal evidence that investments in cities where the state-owned firm and the private firm compete are more likely to be complements than substitutes what makes a crowding out unlikely to occur.

The concern whether a state-owned firm will crowd out private investment is justified if the two discussed conditions are satisfied. Otherwise, state-owned firms and private firms should be allowed to compete in the same market since the state-owned firm does not have a strategic incentive to crowd out private investment. The analysis also shows that the presence of a state-owned firm in a market is crucial: adhering to a political agenda is neither necessary nor sufficient for strategic crowding out to occur.

Essay 2 studies the aftermath of the financial crisis and how several countries have used public funds to bail out private companies. At the same time, managerial compensation in several of these companies has soared to exorbitant amounts. A public debate about managerial compensation in general and executive bonuses in particular has emerged and, consequently, has forced governments to intervene with appropriate instruments. Several countries have implemented a bonus tax on bonuses paid to managers in firms that received bailout funds. For instance, the United States House of Representatives approved a 90% tax on bonuses in state-supported firms. Ireland enforced a 90% tax on executives' bonuses in firms that received taxpayer aid. The United Kingdom introduced a 50% tax on bankers' bonuses during several months in 2010. Switzerland's Council of States debated taxing executive bonuses that exceeded CHF 3 million. However, the implications of such a tax in terms of the principal's and agent's incentives are not very well understood and the literature has not yet paid enough attention to this controversial issue.

The essay addresses the incentive effect of bonus taxes by analyzing the principal's and agent's behavior in a principal-agent model based on an article by Holmstrom and Milgrom (1987). We analyze how the bonus tax impacts executive pay and then examine the implications on the agent's incentive to exert effort, the composition of the executive's compensation package (fixed salary and bonus rate) and the agent's bonus payment and overall salary. The principal decides on the fixed salary and the bonus rate, thereby taking into account the agent's participation constraint and optimal effort level. We also establish the incentive compatibility constraint with the agent's maximization where the principal controls the agent's effort level by choosing the appropriate bonus rate.

We derive three key insights. First, for a general effort cost function, the agent unambiguously lowers the exerted effort due to the bonus tax whereas the principal's behavior in terms of the salary composition depends on the agent's risk aversion and firm specific values. Second, counter to intuition, a higher bonus tax does not necessarily shift the compensation package towards a higher fixed salary. In fact, the opposite can occur: although the intention was to lower the bonus payment with a bonus tax, the bonus might increase due to the levied tax. Third, we apply our results to real-world markets where our model might help to predict how a bonus tax changes the size of the bonus rate and the agent's salary structure. We rely on the corresponding economic environment and the economic fundamentals and present three examples of industries for which our model predictions are likely to be satisfied.

The analysis suggests that the consequences of a bonus tax must be carefully considered because the effects might run against the intended objectives. Firms simply restructure their compensation schemes in reaction to the implementation of a bonus tax and thus it does not eliminate the payment of exorbitant bonuses. Politicians might therefore ignore spill-over effects that have an economic impact.

Essay 3 addresses the liberalization of regulated markets. To open up certain markets to competition, several countries have started to liberalize regulated services or to provide access to networks, most notably, the liberalization of the postal sector and the provision of network access in the telecommunications industry. In these markets, incumbents face the challenge of addressing attacks on product quality and price. Entrants, on the other hand, must strategically and optimally position their product in relation to the incumbent's product position.

Optimal market positioning of products is intensively discussed in a wide range of economic and marketing literature. In earlier years, the literature mainly confronted the issue from a different perspective: how existing brands serve as an indicator about how to attack with a new brand. Hauser and Shugan (1983) challenged this traditional analysis of offensive new-brand positioning and explored the defending firm's optimal behavior if attacked by an entrant (defender model). They did not limit the scope of strategic instruments to the dimension of price but allowed for quality attribute adjustments as well.

In this essay, we study a more specific version of the defender model originally pioneered by Hauser and Shugan (1983) and explicitly model a firm's cost structure associated with its product attributes. Hence, we enrich the original model by adding more structure and specifically model the cost associated with quality attributes in a profit function. The results allow to devise optimal defending strategies based on industry specific cost and market structures. Applying these insights to the postal sector and the telecommunications industry, we identify and explain certain market peculiarities. In the model, two firms compete in three dimensions: two quality attributes which impact fixed and variable costs and product pricing.

We derive two key results. First, we calculate the two incumbent's reaction tables based on the firm's cost structure (rate between fixed and variable costs). The analysis reveals how an incumbent's reaction critically depends on its market share and on the firm's cost structure. Second, we apply the established results to the postal sector and to the telecommunications industry and explain observed investment behaviors of firms in these markets.

The postal sector has traditionally relied on a reserved area to finance the universal service obligations. Recently, many countries have started to liberalize this area and open it up to competition. The prospect of profit attracts new firms that mainly compete in the least cost product segment. Thus, they will choose a very selective market entry and not deliver to rural and less dense areas where expensive technology is required. The incumbent already owns high cost technology to satisfy the universal service obligations.

Policy makers must be aware of these market forces when liberalizing the postal sector. In order to ensure that people in rural and less populated areas will be served, the government must provide benefits to attract firms there (e.g., subsidizing certain services).

In the telecommunications industry, regulation plays a crucial role in encouraging market entries and maintaining competition. We provide a consistent theoretical framework for the empirical evidence derived by Grajek and Röller (2012) and Briglauer, Ecker, and Gugler (2012). They highlight the inherent regulation/investment trade-off that access regulation might lead to higher competition and lower prices but also undermines investment incentives over time. We confirm this relationship: an investment in an own network by the entrant encourages the incumbent to enhance its network quality as well. If access regulation is provided, the entrant attacks with a technology that creates services based on the incumbent's infrastructure and need not bear the fixed costs to build its own network.

Recently, fibre deployment of future telecommunication is a fiercely debated challenge of regulators and investing firms at the same time. There, the prospective to a grant network access in the future might prevent potential firms from investing. If network access is granted, conditions must be set such that the network provider keeps investing in network quality and network maintenance. A lack of access regulation eventually leads to infrastructure competition but also to a duplication of the network infrastructure.

Our analysis reveals the challenges that governments face when liberalizing markets. They have to design a legal framework which correctly incentivizes all parties.

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6 References

1

When Do State-Owned Firms Crowd Out Private Investment?*

joint with Stefan Buehler

Abstract

This essay examines the conditions under which a state-owned firm with a political agenda strategically crowds out investment by a private firm. Employing reduced-form analysis, we show that strategic crowding out occurs if (i) the private firm regards investments as strategic substitutes, and (ii) private investment is undesirable from the state-owned firm's perspective. We discuss how our analysis applies to real-world markets and argue that it provides an explanation for the ambivalent evidence on the effect of public on private investment: State ownership is neither necessary nor sufficient for crowding out to occur.

1.1 Introduction

Competition between state-owned firms and private firms is a commonplace phenomenon in market economies. Traditionally, state-owned firms play an important role in the provision of network infrastructure in telecommunications, energy, and railroads, but they also operate in many other industries. La Porta, de Silanes, and Shleifer (2002) and Andrianova, Demetriades, and Shortland (2012), for instance, show that government ownership of banks

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is pervasive around the world.[1] Also, it is well known that state-owned firms compete with private firms in extracting crude oil and other crude materials, manufacturing aircraft and cars, broadcasting, education, health care, insurance, etc.

While there has been considerable debate regarding the pros and cons of state-owned firms (we will discuss the related literature in Section 2),[2] the strategic interaction of investment decisions by state-owned and private firms is not very well understood. In particular, the literature has largely ignored the common concern that state-owned firms might *crowd out* investment by private firms. This concern is particularly relevant in industries where firms must make large up-front investments (e.g., in building network infrastructure, enhancing product design, ramping up advertising campaigns, etc.) to compete effectively in the product market.

In this essay, we provide a formal analysis of the strategic interaction of investment and pricing decisions by state-owned and private firms, and we work out the conditions under which a state-owned firm strategically crowds out investment by a private firm. Specifically, we model the rivalry between a state-owned firm and a private firm as a duopoly with differentiated products, allowing for the possibility that the state-owned firm adheres to a "political agenda." In doing so, we account for the fact that the state-owned firm might be under political pressure from the politicians who control it (Shleifer and Vishny, 1994; Bennedsen, 2000).[3] Assuming that firms make demand-enhancing investments before they compete in the product market, we employ reduced-form analysis and the taxonomy of business strategies introduced by Fudenberg and Tirole (1984) to characterize strategic public and private investment.

Our key result is that, for strategic crowding out to occur, two conditions must be satisfied: (i) the private firm regards investments as strategic substitutes; (ii) private investment is "undesirable" from the state-owned firm's perspective. The intuition for this result is straightforward. If the private firm regards investments as strategic substitutes (complements, respectively), an increase in the state-owned firm's investment reduces (increases) private investment. Consequently, public investment can crowd out private investment only if the private firm regards investments as strategic substitutes (condition (i)). Moreover, the state-owned firm must have an incentive to strategically crowd out private investment. This incentive is generated by an adverse effect of private investment on the state-owned firm, in which case private investment is undesirable from the state-owned firm's perspective (condition (ii)). We will make this intuition more precise below.

Our analysis provides a consistent explanation for the ambivalent empirical evidence on the effect of public investment on private investment (David, Hall, and Toole, 2000):[4]

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[1] In a related paper, La Porta, de Silanes, and Shleifer (1999) find that, in 28 wealthy economies around the world, large firms are typically controlled by families or the state.

[2] A special report by *The Economist* (January 21, 2012) on "State Capitalism" provides a useful survey of the public debate.

[3] Our analytical framework will also allow for the possibility that the private firm does not maximize profits.

[4] These authors survey the evidence on public investment accumulated over 35 years. A more recent paper by González and Pazó (2008) examines whether public *subsidies* stimulate private R&D spending of Spanish

Since the extent to which conditions (i) and (ii) are satisfied depends on the details of the industry under study, estimates of the effect of public investment on private investment are unlikely to be robust across industries. The linear demand example considered in Section 1.4 below illustrates this: Allowing for a business-stealing effect of private investment is sufficient to turn strategic complements into strategic substitutes, even if everything else remains unchanged.

To see how our analysis can be applied to real-world markets, consider the telecommunications industry where "next-generation" fibre-optic networks are being built in many industrialized countries (Body of European Regulators for Electronic Communications, 2010; Noam, 2010). In Switzerland, for instance, there are several cities (e.g., Basel, Geneva, and Zurich) in which both the local public utility and Swisscom, the country's leading telecommunications operator, invest in fibre-optic networks. There is anecdotal evidence that, in some of these cities, the local public utility's investment has encouraged Swisscom's investment (cf. Body of European Regulators for Electronic Communications, 2010, pp. 8). This suggests that investments in fibre-optic networks in urban areas are viewed as strategic complements (rather than substitutes) in Switzerland, such that strategic crowding out is unlikely to be a concern.[5]

We are well aware that our simple analytical framework necessarily provides an incomplete description of the rivalry between state-owned firms and private firms in real-world markets. In particular, it treats the political pressure on the state-owned firm in a reduced-form manner and does not derive the political agenda from first principles. Nevertheless, we are convinced that our analytical framework captures the essence of strategic interaction in public and private investments in many real-world markets. Our analysis shows that the role of state ownership in explaining strategic crowding out is subtle: Adhering to a political agenda is neither necessary nor sufficient for strategic crowding out to occur.

The remainder of this essay is structured as follows. In Section 1.2, we discuss the related literature. Section 1.3 introduces the analytical framework, motivates the modeling of the political agenda, and identifies the conditions under which the state-owned firm practices strategic crowding out. In Section 1.4, we illustrate our analysis with a simple linear demand example. Section 1.5 discusses implications of our analysis, and Section 1.6 concludes.

1.2 Related Literature

The economic analysis of state-owned firms has made great progress over the last few decades. In this section, we briefly discuss how our essay relates to three relevant strands of the literature.

First, our essay adds to the debate on state versus private ownership. In an authoritative survey of this debate, Shleifer (1998, p. 138) rejects the view (widely held in the 1940s)

manufacturing firms. They find no evidence for crowding out.

[5]It is worth noting that the strategic complementarity in investments is often supported by cooperation contracts between the local public utilities and Swisscom.

that government production is broadly desirable and makes a case for the "superiority of private ownership". Based on Grossman and Hart (1986), Hart and Moore (1990), Hart (1995), and Hart, Shleifer, and Vishny (1997), he argues that private ownership provides stronger incentives to reduce cost and invest in non-contractible quality or innovation. State ownership is thus desirable only if efficient production requires soft incentives (e.g., to avoid cost cutting that has adverse effects on non-contractible quality). The balance is further tilted against state ownership, as state-owned firms might be under political pressure from the politicians who control them to transfer resources to their supporters (Shleifer and Vishny, 1994; Bennedsen, 2000).[6]

Our analysis builds on these insights and allows for the possibility that a state-owned firm adheres to a political agenda.[7] However, since we want to focus on the strategic interaction of public and private investments, we represent the political pressure on a firm in a reduced-form manner by a simple policy agenda function which depends on the endogenous variables of our model (i.e., prices and investments). This is in line with Vickers and Yarrow (1988, 1991) and allows us to confine ourselves to a simple two-stage game framework to study strategic crowding out.

Second, our essay adds to the "mixed" oligopoly literature, which typically makes the peculiar assumption that state-owned firms maximize welfare and compete with profit-maximizing private firms (i.e., firms are not allowed to adhere to a political agenda). Cremer, Marchand, and Thisse (1991) and Anderson, de Palma, and Thisse (1997), for instance, analyze mixed price competition with differentiated products, but these authors abstract from endogenous investments. A number of papers have integrated endogenous public and private investments into very specific models of mixed oligopoly (e.g. Delbono and Denicolò, 1993; Poyago-Theotoky, 1999; Matsumura and Matsushima, 2004; Ishibashi and Matsumura, 2006). It is important to note, though, that none of these papers considers demand-enhancing investments or provides a taxonomy of strategic investment behavior.

Third, our analysis sheds new light on the empirical evidence on the interaction of public and private investment. As noted above, the evidence on the interaction of public and private investment is ambivalent. The extensive survey by David, Hall, and Toole (2000, p. 525) deliberately avoids "any definitive empirical conclusions regarding the sign and magnitude of the relationship between public and private R&D". This reluctance is justified on the grounds that there is no unified framework for the analysis of the interaction of investments at the micro and macro level, and that it is difficult to compare empirical studies which focus on the impact of different types of public investment.[8]

By offering a simple but general taxonomy of strategic investment at the firm level, our essay helps to organize the micro-level evidence on the interaction of public and private

[6] Similar arguments are put forward in favor of privatizing state-owned firms. Important theoretical contributions to the privatization literature include Laffont and Tirole (1991), Boycko, Shleifer, and Vishny (1996), Schmidt (1996a,b), and Che (2009). Megginson and Netter (2001) provide a survey of the empirical evidence.

[7] In line with Glaeser and Shleifer (2001), we also allow for the possibility that the private firm does not maximize profits.

[8] The latter problem is also emphasized by Laopodis (2001), who examines the effects of military and non-military public expenditures on gross private investment in four different European economies.

investment. It highlights the importance of accounting for market-specific details to understand the interaction of public and private investment. The effect of public investment on private investment may vary considerably across industries.

1.3 Model

1.3.1 Basic Setup

We consider a duopoly model with differentiated products indexed by $i, j = 1, 2$.[9] Product demand is given by $D_i(\boldsymbol{p}, \boldsymbol{\theta})$, where $\boldsymbol{p} = (p_i, p_j)$ and $\boldsymbol{\theta} = (\theta_i, \theta_j)$, $i \neq j$, denote prices and investments, respectively. We consider a two-stage game in which firms make investments in the first stage and compete in prices in the second stage.

We impose the following (standard) assumptions on the demand and cost functions:

A 1.1. *Products are demand substitutes, i.e.,* $\partial D_i / \partial p_i < 0$, *and* $\partial D_i / \partial p_j \geq 0$, $i, j = 1, 2$, $i \neq j$.

A 1.2. *Investment strictly increases own demand and weakly decreases demand for the other product, i.e.,* $\partial D_i / \partial \theta_i > 0$ *and* $\partial D_j / \partial \theta_i \leq 0$, $i, j = 1, 2$, $i \neq j$.

A 1.3. *Firms face constant marginal costs* $c_i \geq 0$ *and make investments at convex cost* $F_i(\theta_i),\ i = 1, 2$.

Using Assumptions (A 1.1)-(A 1.3), firm i's profits in the second stage are given by

$$\pi_i(\boldsymbol{p}, \boldsymbol{\theta}) = (p_i - c_i) D_i(\boldsymbol{p}, \boldsymbol{\theta}) - F_i(\theta_i).$$

Now, following Vickers and Yarrow (1988, 1991) and building on Shleifer (1998) and Bennedsen (2000), we allow for the possibility that firm i adheres to a "political agenda" $A_i(\boldsymbol{p}, \boldsymbol{\theta})$, such that it effectively maximizes the objective function

$$\Pi_i(\boldsymbol{p}, \boldsymbol{\theta}) = \pi_i(\boldsymbol{p}, \boldsymbol{\theta}) + \lambda_i A_i(\boldsymbol{p}, \boldsymbol{\theta}),$$

where $\lambda_i \in \{0, 1\}$ indicates whether firm i's behavior is affected by a political agenda. Notice that, just like the profit function π_i, the political agenda A_i depends on the endogenous variables $(\boldsymbol{p}, \boldsymbol{\theta})$. The political agenda can thus be interpreted to provide a measure of the "political profit" generated by a particular choice of prices and investments.

To ensure existence and uniqueness of a price equilibrium, we impose the following assumption:

A 1.4. *Prices are strategic complements (*$\partial^2 \Pi_i / (\partial p_i \partial p_j) \geq 0$*), and the contraction condition* $\partial^2 \Pi_i / (\partial p_i)^2 + |\partial^2 \Pi_i / (\partial p_i \partial p_j)| < 0$ *holds (Gallego et al., 2006; Vives, 2001).*

[9] Under appropriate assumptions, our reduced-form analysis generalizes naturally beyond the duopoly setting.

Finally, to simplify exposition, we let $\varepsilon_{ij} \equiv -(\partial D_j/\partial p_i)/(D_j/p_i)$ denote the price elasticity of demand, and we define $\hat{X}_{ii} \equiv (\partial X_i/\partial p_j)(\partial p_j/\partial \theta_i) + \partial X_i/\partial \theta_i$ and $\hat{X}_{ij} \equiv (\partial X_i/\partial p_j)(\partial p_j/\partial \theta_j) + \partial X_i/\partial \theta_j$, respectively. This notation allows us to represent the first-order conditions in a convenient form.

Applying the envelope theorem, prices and investments in the interior subgame-perfect Nash equilibrium satisfy the first-order conditions

$$\frac{p_i - c_i}{p_i} = \frac{1}{\varepsilon_{ii}}\left(1 + \lambda_i \frac{1}{D_i}\frac{\partial A_i}{\partial p_i}\right), \tag{1.1}$$

$$(p_i - c_i)\hat{D}_{ii} + \lambda_i \hat{A}_{ii} = \frac{\partial F_i}{\partial \theta_i}. \tag{1.2}$$

Equations (1.1) and (1.2) nest the standard duopoly (where both firms maximize profits, $\lambda_1 = \lambda_2 = 0$), the mixed duopoly (where one firm maximizes profits, $\lambda_1 \neq \lambda_2$), and the welfare benchmark ($\lambda_1 = \lambda_2 = 1$) as special cases.[10] They indicate that the political agenda A_i plays an intuitive role for equilibrium pricing and investment: The derivatives of A_i with respect to p_i and θ_i, respectively, determine the extent to which equilibrium prices and investments are distorted away from standard profit-maximizing choices. For instance, if the political pressure on state-owned firm i is such that its political agenda function is decreasing in own price ($\partial A_i/\partial p_i < 0$), the equilibrium price p_i is distorted downwards. Similarly, if the political agenda function is increasing in own investment ($\hat{A}_{ii} > 0$), the equilibrium investment θ_i is distorted upwards.

1.3.2 Identifying Crowding Out

We now study the conditions under which the state-owned firm will strategically crowd out private investment, using the taxonomy of business strategies introduced by Fudenberg and Tirole (1984).[11]

Let us first consider the condition under which investment by firm j is *desirable* from firm i's point of view. We say that investment by firm j is desirable from firm i's perspective (i.e., makes firm j "soft") if

$$\frac{d\Pi_i}{d\theta_j} = (p_i - c_i)\hat{D}_{ij} + \lambda_i \hat{A}_{ij} > 0, \tag{1.3}$$

whereas investment is *undesirable* (makes firm j "tough") if $d\Pi_i/d\theta_j < 0$. Put differently, firm j's investment is desirable from firm i's point of view if it increases the value of its objective function. It is important to note that firm i's political agenda may affect its assessment of investments by firm j. For instance, a positive effect of firm j's investment on firm i's political agenda (i.e., $\hat{A}_{ij} > 0$) may dominate a negative effect on profits $(d\pi_i/d\theta_j < 0)$, leading to a positive overall assessment of firm j's investment ($d\Pi_i/d\theta_j > 0$).

[10] In the latter cases, a state-owned firm maximizes social welfare by assumption, such that $A_i = \pi_j + \int D_i dp_i + \int D_j dp_j, i, j = 1, 2, i \neq j$.

[11] Functions are evaluated at equilibrium quantities throughout this section.

Next, consider the nature of strategic interaction in investment decisions. From firm j's point of view, investments are *strategic substitutes* if

$$\frac{\partial^2 \Pi_j}{\partial \theta_j \partial \theta_i} = \frac{\partial \hat{D}_{jj}}{\partial \theta_i}(p_j - c_j) + \hat{D}_{jj}\frac{\partial p_j}{\partial \theta_i} + \lambda_j \frac{\partial \hat{A}_{jj}}{\partial \theta_i} < 0 \tag{1.4}$$

and *strategic complements* if $\partial^2 \Pi_j/(\partial \theta_j \partial \theta_i) > 0$ (cf. Bulow, Geanakoplos, and Klemperer, 1985). Intuitively, if investments are strategic substitutes (complements, respectively), the optimal investment of firm j decreases (increases) with investment by firm i. Again, it is important to note that the political agenda might affect firm j's assessment of the nature of strategic interaction. In particular, a negative impact of firm i's investment on the effect of firm j's investment on its own political agenda (i.e., $\partial \hat{A}_{jj}/\partial \theta_i < 0$) may change the sign of $\partial^2 \Pi_j/(\partial \theta_j \partial \theta_i)$ from positive to negative.

Using equations (1.3) and (1.4), Table 1.1 characterizes the strategic interaction in investments by a state-owned firm and a private firm. We assume that the row player is the state-owned firm i which maximizes Π_i and adheres to a political agenda (i.e., $\lambda_i = 1$), whereas the column player is the private firm j which maximizes profits π_j (i.e., $\lambda_j = 0$).[12]

Table 1.1: Strategic Investment by a State-Owned Firm with a Political Agenda

		Private firm j regards inv. as	
		strat. substitutes $\frac{\partial^2 \pi_j}{\partial \theta_j \partial \theta_i} < 0$	*strat. complements* $\frac{\partial^2 \pi_j}{\partial \theta_j \partial \theta_i} > 0$
State-owned firm i finds private inv.	*desirable* $\frac{d\Pi_i}{d\theta_j} > 0$	underinvestment “puppy dog”	overinvestment “fat cat”
	undesirable $\frac{d\Pi_i}{d\theta_j} < 0$	overinvestment “top dog” **crowding out**	underinvestment “lean & hungry look”

Desirable Private Investment

Let us first consider the case where private investment is desirable from the state-owned firm's point of view ($d\Pi_i/d\theta_j > 0$). Clearly, in this case, the state-owned firm will want to strategically *promote* (rather than crowd out) private investment. To do so, the state-owned

[12] The extension to the case where firm j also adheres to a political agenda is straightforward.

firm will adopt a "puppy dog" strategy (i.e., strategically underinvest) if investments are strategic substitutes from the private firm's point of view. If the private firm regards investments as strategic complements, however, the state-owned firm will adopt a "fat cat" strategy (i.e., strategically overinvest) to promote private investment. It is worth emphasizing that, if the state-owned firm strategically overinvests, it does so to boost private investment.

Undesirable Private Investment

Consider now the case where private investment is undesirable from the state-owned firm's point of view ($d\Pi_i/d\theta_j < 0$). In this setting, the state-owned firm will indeed want to strategically *reduce* private investment. To do so, it will adopt a "top dog" strategy (i.e., strategically overinvest) if investments are strategic substitutes and a "lean & hungry look" strategy (i.e., strategically underinvest) if investments are strategic complements from the private firm's point of view. This implies that the only setting in which the state-owned firm overinvests to strategically *crowd out* private investments is the top dog setting (i.e., crowding out does not automatically follow from strategic substitutes).

Summary

Table 1 highlights that, for strategic crowding out to occur, two conditions need to be satisfied: (i) the private firm regards investments as strategic substitutes; (ii) private investment is not desirable from the state-owned firm's perspective. Note that there is only *one way* in which the political agenda can cause strategic crowding out: It might render private investment undesirable rather than desirable—i.e., change the sign of $d\Pi_i/d\theta_j$ from positive to negative "for political reasons"—when the private firm regards investments as strategic substitutes. Otherwise, strategic overinvestment will either also be practiced by a private firm without a political agenda (if $d\Pi_i/d\theta_j$ is negative to begin with) or it will boost private investment (if investments are strategic complements from the private firm's perspective). Adhering to a political agenda is thus neither necessary nor sufficient for crowding out to occur.

1.4 Linear Demand Example

We illustrate our analysis with a linear demand example for which we can derive closed-form solutions for equilibrium prices and investments. Specifically, we assume that demand is given by

$$D_i(\boldsymbol{p}, \boldsymbol{\theta}) = \alpha - \beta p_i + \gamma p_j + \theta_i - \tau\theta_j,$$

where $\alpha > 0$ and $\beta > \gamma > 0$ are parameters and $\tau \in \{0, 1\}$ indicates whether investment has a direct business-stealing effect.[13] Let firm 1 be the state-owned firm ($\lambda_1 = 1$) and assume, for simplicity, that its political agenda is to maximize total investment, i.e.,

$$A_1(\boldsymbol{p}, \boldsymbol{\theta}) = \omega(\theta_1 + \theta_2),$$

[13] This demand function satisfies the relevant assumptions (A 1.1) and (A 1.2).

where $\omega \geq 0$ measures the weight of the political agenda.[14] Suppose that firm 2 is privately owned and maximizes profits ($\lambda_2 = 0$). Finally, assume that marginal costs are normalized to zero ($c_1 = c_2 = 0$) and that investment costs are quadratic, i.e., $F_i(\theta_i) = \theta_i^2$.

Let us now employ Table 1 to characterize equilibrium behavior. Tedious but straightforward calculations show that, from firm 2's perspective,

$$\frac{\partial^2 \pi_2}{\partial \theta_2 \partial \theta_1} = \frac{2\beta(2\beta - \gamma\tau)(\gamma - 2\beta\tau)}{(4\beta^2 - \gamma^2)^2},$$

such that, from the private firm's perspective, investments are strategic substitutes if they give rise to business stealing (i.e., $\partial^2 \pi_2/(\partial\theta_2\partial\theta_1)|_{\tau=1} < 0$) and strategic complements in the absence of business stealing (i.e., $\partial^2 \pi_2/(\partial\theta_2\partial\theta_1)|_{\tau=0} > 0$).

Firm 1's optimal behavior also depends on the weight of its political agenda. To see this, notice that $d\Pi_1/d\theta_2$ is negative at $\omega(\tau) = 0$[15] and monotone increasing in ω. There is thus a critical weight $\omega^*(\tau)$ below (above) which investment by the private firm 2 is undesirable (desirable, respectively) from the state-owned firm's perspective. As a result, depending on parameter values, one of the strategies listed in Table 1 will be adopted in equilibrium. Figure 1.1 illustrates the different scenarios for the parameter values $\alpha = 0.5$, $\beta = 1$, and $\gamma = 0.7$.

First, consider the case of *strategic substitutes* ($\tau = 1$). Panel A shows that the reaction functions $R_1(\omega)$ and R_2 are downward-sloping, and that an increase in the weight of the political agenda ω shifts out the state-owned firm's reaction function $R_1(\omega)$. Intuitively, this shift follows from the fact that, for any given level of private investment, the best-response investment of the state-owned firm is higher, as an increase in ω makes public investment more valuable. Panel B highlights that firm 1 adopts a top dog (puppy dog) strategy for $\omega(\tau)$ below (above, respectively) the critical weight $\omega^*(1)$. That is, the state-owned firm 1 strategically crowds out (i.e., overinvests to reduce private investment) if investments are strategic substitutes and the weight of the political agenda ω is sufficiently small.[16] However, if the weight of the political agenda becomes sufficiently large, the state-owned firm strategically underinvests, because private investment is now desirable due to the political agenda, but investments remain strategic substitutes from the private firm's perspective. Panel B also shows that equilibrium investments are symmetric and do not vary in ω if both firms solely maximize profits ($\lambda_i = 0, i = 1, 2$).

Next, consider the case of *strategic complements* ($\tau = 0$). Panel C shows that the reaction functions $R_1(\omega)$ and R_2 are now upward-sloping, and that an increase in ω again shifts out $R_1(\omega)$ (as above, the intuition is that public investment becomes more valuable). Panel D highlights that, for the given parameter values, firm 1 adopts a fat cat strategy for any admissible $\omega(\tau) \geq 0$. The state-owned firm 1 will thus never adopt a lean & hungry

[14] Such a political agenda may be induced, for instance, by a concern for sufficient infrastructure investments.

[15] This immediately implies that a privately owned firm 1 (without a political agenda) would find investment by firm 2 undesirable.

[16] Notice that crowding out would also be practiced by a privately owned firm 1.

look strategy.[17] Again, investments do not vary in ω if both firms solely maximize profits.

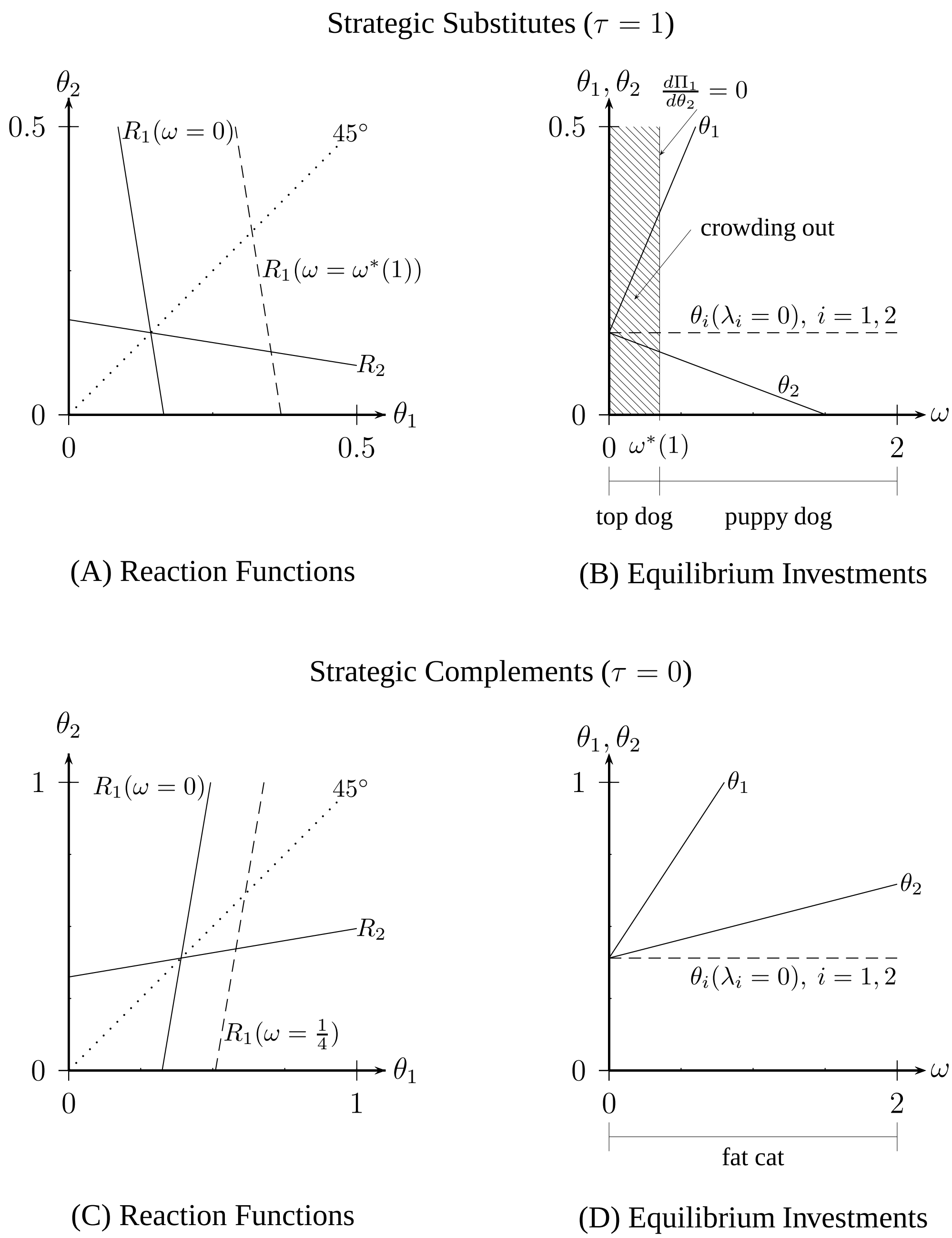

Figure 1.1: Reaction functions and equilibrium investments with linear demand and political agenda $A_1 = \omega(\theta_1 + \theta_2)$

[17]The critical weight $\omega^*(0)$ below which firm 1 would adopt a lean & hungry look strategy is negative.

1.5 Implications

Our analysis highlights that, for strategic crowding out to occur, two conditions must be satisfied: (i) the private firm regards investments as strategic substitutes, and (ii) private investment is undesirable from the state-owned firm's perspective. In principle, it is thus straightforward to check whether crowding out is a concern in a particular industry: all one needs to do is check whether these conditions are satisfied in the industry under study.

In practice, it is convenient to adopt a *two-step procedure*: First, one should look for evidence that investments are strategic complements (such that crowding out cannot occur). In the introduction, we have used this approach to understand the interaction of public and private investments in next-generation telecommunication networks in Switzerland. Based on anecdotal evidence, we have argued that the relevant Swiss firms seem to regard investments as strategic complements and concluded that crowding out is unlikely to be a concern. Second, if investments are likely to be strategic substitutes, one should look for hints whether private investment is undesirable from the state-owned firm's perspective. Private investment is typically undesirable if it has a business-stealing effect or another adverse effect on a state-owned firm with a political agenda. The latter may reflect, for example, a concern for goods such as public health (e.g., alcoholic beverages, health insurance, immunization), public security (e.g., fire service, property insurance, security services), or environmental protection (e.g., solar power, waste disposal). In such industries, it is plausible that a state-owned firm might want to practice strategic crowding out.

This two-stage procedure offers a simple micro-founded approach to predict whether crowding out is a problem in a particular industry. It should be clear that, while this procedure arguably works well at the micro level, it is ill-suited to guide empirical work on crowding out at the macro level.

1.6 Conclusion

This essay has analyzed the conditions under which a state-owned firm with a political agenda strategically crowds out investment by a private firm. Employing a simple reduced-form two-stage game, we have shown that a state-owned firm strategically crowds out private investment in markets where the private firm regards investments as strategic substitutes and private investment is undesirable from the state-owned firm's perspective. Our analytical framework captures the essence of strategic interaction in investments in mixed markets, and it suggests a simple two-step procedure to test whether crowding out is likely to be a concern in a particular industry.

Our analysis shows that state ownership plays a subtle role in explaining strategic crowding out: The political agenda causes crowding out only if it actually makes private investment undesirable when investments are strategic substitutes. Otherwise, crowding out will either also be practiced by a private firm, or public investment will boost private investment. State ownership is thus neither necessary nor sufficient for crowding out to occur. This helps to explain why it has been difficult to provide convincing empirical evidence on the effect of public investment on private investment.

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22 References

2

Incentive Effects of Bonus Taxes in a Principal-Agent Model*

joint with Helmut M. Dietl, Martin Grossmann, and Markus Lang

Abstract

Several countries have implemented bonus taxes for corporate executives in response to the current financial crisis. Using a principal-agent model, this essay investigates the incentive effects of bonus taxes by analyzing the agent's and principal's behavior. Specifically, we show how bonus taxes affect the agent's incentives to exert effort and the principal's decision regarding the composition of the compensation package (fixed salary and bonus rate). We find that, surprisingly, a bonus tax can increase the bonus rate and decrease the fixed salary if the agent is highly risk averse. Additionally, a bonus tax can induce the principal to pay higher bonuses even though the agent's effort unambiguously decreases. Nevertheless, a bonus tax reduces the overall salary of the agent. Further results are derived with respect to the existence and uniqueness of the equilibrium for a general effort cost function.

2.1 Introduction

In response to the current financial crisis, several countries have implemented bonus taxes for corporate executives in firms that received large amounts of federal bailout funds. For example, the United States House of Representatives approved a 90% tax on bonuses in

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such firms. Similarly, Ireland introduced in January 2011 a 90% tax on executives' bonuses in banks that received government support. Moreover, in the United Kingdom, a bonus tax of 50% was imposed on bankers' bonuses for a period of several months in 2010. In Switzerland, the Council of States discussed proposals to introduce a tax on executive bonuses above CHF 3 million.

Despite their political relevance, the economic effects of bonus taxes have received little attention in academic research. This essay tries to fill part of this gap by developing basic insights into the functioning and consequences of bonus taxes on executive pay based on the principal-agent model of Holmstrom and Milgrom (1987). We introduce a tax that is levied on the agent's bonus to analyze how it affects the agent's incentive to exert effort, the composition of executives' compensation packages (fixed salary and bonus rate) as well as the agent's bonus payment and overall salary. The objective of this essay, however, is not to provide a normative analysis about the desirability of bonus taxes but rather, given their existence in the real world, to analyze the incentive effects of such taxes.

In our model, the principal chooses the fixed salary and the bonus rate by satisfying the agent's participation constraint and anticipating the agent's optimal effort level. For a general effort cost function, the agent unambiguously reacts to a higher bonus tax with lower effort, while the behavior of the principal depends on the agent's degree of risk aversion and the variance in the firm value. Basic intuition might suggest that by taxing the agent's bonus, the compensation package is shifted to the fixed salary. However, the opposite can occur if the agent is highly risk averse and/or the variance in the firm value is large. Moreover, a bonus tax can lead to the counterintuitive result that both the fixed salary and the bonus rate increase. Surprisingly, a higher bonus tax can induce the principal to pay higher bonuses even though the agent exerts less effort. However, the overall salary of the agent unambiguously decreases through a bonus tax. Further results are derived with respect to the existence and uniqueness of the equilibrium for a general effort cost function.

The remainder of this essay is structured as follows. Section 2.2 briefly reviews the related literature. Section 2.3 introduces our principal-agent model with its main assumptions and notations in Subsection 2.3.1. In Subsection 2.3.2, we solve the model and present the optimality conditions and equilibria. In Subsection 2.3.3, we compute the effects of bonus taxes on the equilibrium outcomes. Finally, Section 2.4 discusses the main insights and presents our conclusions.

2.2 Related Literature

Despite the large body of literature and numerous theoretical and empirical studies on executive compensation, only a few papers have addressed the consequences of executive compensation regulation in general and the effects of bonus taxes in particular. For example, Dew-Becker (2009) reviews the history of government rules and regulations in the United States that affect executive compensation. By discussing disclosure rules, advancements in corporate governance, and say-on-pay, Dew-Becker analyzes the evolution of pay regulation and concludes that mandatory say-on-pay could be the most effective and least harmful measure of controlling executive compensation. Knutt (2005) examines diverse regulatory issues from a legal point of view. He claims that the various attempts to regulate executive compensation, such as the disclosure and tax regulations, have not yet been effective.

Hall and B. (2000) analyze the extent to which tax policy influences the composition of executive compensation and discuss the consequences of rising stock-based pay.[1] Their empirical study shows that the dramatic explosion in executive stock-option pay since 1980 cannot be attributed to tax rate changes. Moreover, the so-called million dollar rule induced a substitution from fixed salary toward performance-related pay. Unlike Hall and B. (2000), who concentrate on a tax on stock-based pay, we study a tax that is levied on the agent's bonus.

Radulescu (2010) analyzes the effects of bonus taxes in a two-country, principal-agent model with relocation possibilities for the managers. The paper focuses on tax incidence and analyzes the effects of bonus taxes on firm profits, dividends and welfare in the case of a quadratic effort cost function. The paper shows that a bonus tax induces lower profits and dividends so that the incidence is borne by the shareholders. The welfare implications of bonus taxes depends on the relocation possibilities for the managers. In contrast to our model, in which we focus on the incentive effects of bonus taxes for a general cost function and derive an ambiguous effect of a bonus tax on the fixed and variable salary, Radulescu (2010) finds that the effort-based compensation component (bonus) unambiguously increases with a higher bonus tax.[2]

Finally, there is now a growing literature on regulating incentive pay in the financial sector.[3] For example, Hakenes and Schnabel (2012) show that the presence of bailout guarantees induce bankers to increase their risk-taking behavior and lead to a steeper compensation scheme. An upper limit on the bonus could alleviate these problems. Bolton, Mehran, and Shapiro (2010) develop a theoretical model to show that the credit default swap reduces risk taking of executives at highly levered financial firms. Based on a model of workers in the financial sector, Besley and Ghatak (2011) show that bailouts induce lower effort and higher risk taking.

[1] Based on a large sample of US firms during 1994–2004, Tzioumis (2008) empirically analyzes how the adaptation of CEO stock option plans is influenced by CEO and firm characteristics. Palmon et al. (2008) determine the optimal strike prices of stock options for executives in a simulation model.

[2] Cuñat and Guadalupe (2009) utilize a panel of US executives and find that an increase in the financial sector through deregulations in the 1990s induced an increase in the variable and a decrease in the fixed components of executive pay. Using data from Germany, Kraft and Niederprüm (1999) show that a higher variance in firm profits decreases the variable salary component. Finally, Graziano and Parigi (1998) show in a principal agent model that more competition represented by a higher number of firms induces the agent to decrease efforts in the case of a low product differentiation.

[3] Bebchuk and Spamann (2010) identify the underlying mechanisms regarding the compensation structures for bankers that have produced incentives for excessive risk-taking.

2.3 Model

2.3.1 Notations and Assumptions

Our model is based on the principal-agent model of Holmstrom and Milgrom (1987) and introduces a tax denoted by $\tau \in (0, 1)$ that is levied on the agent's variable salary (bonus). We consider a single-period employment relationship in a firm between a risk-neutral principal (e.g., a firm's owner) and a risk-averse agent (e.g., CEO). The agent chooses the unobservable action (effort) $a \in \mathbb{R}_0^+$ to produce a firm value given by $x = a + \varepsilon$, where ε is a normally distributed error term with $\varepsilon \sim N(0, \sigma_\varepsilon^2)$ representing potential effects on the firm value beyond the agent's control.[4] A high variance in the error term σ_ε^2 can be interpreted as a more uncertain economic environment that creates a high variance in the firm value or a situation in which the agent's performance cannot be measured precisely.

Because the principal can only observe the firm value x, the agent's effort a cannot be specified in a legally enforceable contract. The agent's effort generates costs according to a strictly convex cost function $c(a) \in C^3$ that satisfies

A 2.1. $c'(a) > 0, c''(a) > 0$ *for* $a > 0$, $c'(0) = c''(0) = 0$. *Moreover,* $c'''(a) \geq 0$ *for* $a \geq 0$ *and* $\lim\limits_{a \to \infty} c'(a) = \infty$.

In line with the agency literature, we assume that the principal offers the agent a linear employment contract that generates a payoff to the agent according to[5]

$$w(x) \equiv s + (1 - \tau)bx = s + (1 - \tau)b(a + \varepsilon),$$

where $s \in \mathbb{R}_0^+$ is the fixed salary component and bx is the variable salary or bonus payment given by the principal. We follow Gibbons (1998, p. 116) and refer to the incentive-based component $b \in (0, 1)$ as the bonus rate.[6] It should be noted that the gross salary paid by the principal is given by $W(x) \equiv s + bx$, and that $w(x) \equiv s + (1 - \tau)bx$ is the net-of-tax salary received by the agent. The state receives the difference between gross and net salary as tax revenue τbx. We further assume that the agent has an exogenously-given outside option, represented by his reservation utility $\widehat{u} \in \mathbb{R}_0^+$. The reservation utility can be interpreted as

[4] Because we want to focus on the incentive effects of bonus taxes in a microeconomic environment of a firm and its employee, we neglect possible negative externalities of the agent's behavior on the economy as a whole. Hence, in our model, we do not analyze how a bonus tax might correct potential inefficiencies of the employment contract between the principal and the agent. Moreover, we do not aim to investigate how a bonus tax influences the risk-taking behavior of corporate executives.

[5] Linear contracts are widely used in the literature because of their analytical convenience (see, e.g., Feltham and Xie, 1994; Baker, 2002; Hughes, Zhang, and Xie, 2005). Holmstrom and Milgrom (1987) found the optimal dynamic compensation scheme to be linear for certain intertemporal contracting problems where the agent controls a stationary technology. Hellwig and Schmidt (2002) show that the result of Holmstrom and Milgrom (1987) does not only apply to continuous-time but also to discrete-time settings.

[6] Note that in the literature on executive compensation b is also referred to as the pay-performance sensitivity (PPS) or piece rate (see, e.g., Jensen and Murphy, 1990; Murphy, 1999; Conyon and Sadler, 2001; and Faulkender et al., 2010).

the utility the agent would receive in another firm or in a country without a bonus tax and therefore is assumed to be exogenous.[7]

From the properties of the normal distribution, we derive that the agent's (net-of-tax) salary $w(x)$ is also normally distributed with

$$w(x) \sim N\left(s + (1-\tau)ba; (1-\tau)^2 b^2 \sigma_\varepsilon^2\right).$$

Thus, the expected salary of the agent is given by $E[w] = s + (1-\tau)ba \equiv \overline{w}$, and the variance of the salary is $V[w] = (1-\tau)^2 b^2 \sigma_\varepsilon^2 \equiv \sigma_w^2$.

We assume that the agent is risk-averse with a constant absolute risk-averse (CARA) utility function that is given by the negative exponential function $U(w,a) = -e^{-r(w-c(a))}$, where $r \in \mathbb{R}^+$ is the Arrow-Pratt measure of the agent's degree of absolute risk aversion. The expected value of this utility yields $E[U] \equiv \int U(w,a)f(w)dw$, where $f(w)$ is the probability density function of w. Because the salary is normally distributed with $w \sim N(\overline{w}, \sigma_w^2)$, the expected value of the agent's utility is given by $E[U] = -e^{-r\left(\overline{w}-c(a)-r\sigma_w^2/2\right)}$. Using a monotonic transformation, which preserves the ordering, we conclude that the agent's expected net utility $E[U_A]$ yields

$$E[U_A] \equiv s + (1-\tau)ba - \frac{r\sigma_\varepsilon^2}{2}(1-\tau)^2 b^2 - c(a).$$

The net utility is the certainty equivalent minus costs, where $(1/2)r\sigma_\varepsilon^2(1-\tau)^2 b^2$ characterizes the agent's risk premium required to compensate him for the uncertainty in his expected salary.

The principal is assumed to be risk neutral because she is well diversified. Her profit π_P is the difference between the firm value and the agent's gross salary: $\pi_P \equiv x - W(x) = (1-b)x - s$. Hence, the principal's expected profit is given by

$$E[\pi_P] \equiv (1-b)a - s.$$

The timing is as follows. In $t = 0$, the state sets a certain level for the bonus tax $\tau \in (0,1)$ that is levied on the agent's bonus payment. In $t = 1$, the principal offers the agent an employment contract with a fixed salary s and a bonus rate b. The agent accepts this contract if it guarantees him at least his reservation utility, which is given by $\widehat{u}$. In $t = 2$, after accepting the contract, the agent exerts effort a. In $t = 3$, the firm value x is realized, and all the payments are made in $t = 4$.

2.3.2 Optimality Conditions and Equilibria

The agent maximizes his expected net utility $E[U_A]$ with respect to the effort level a so that the maximization problem is given by

$$\max_{a \geq 0} \left\{ E[U_A] = s + (1-\tau)ba - \frac{r\sigma_\varepsilon^2}{2}(1-\tau)^2 b^2 - c(a) \right\}.$$

[7] In Subsection 2.3.3, we analyze the consequences of an endogenous outside option.

The corresponding first-order condition is

$$\frac{\partial E[U_A]}{\partial a} = (1-\tau)b - c'(a) = 0 \tag{2.1}$$

and has a familiar interpretation. It states that the marginal benefit of effort must be equal to the marginal costs of effort in equilibrium. For a cost function that satisfies Assumption (A 2.1), the second-order condition for a maximum is fulfilled.

The principal maximizes her expected profit $E[\pi_P]$ and solves

$$\max_{(s,b)\geq 0} \{E[\pi_P] = (1-b)a - s\}$$

subject to[8]

$$E[U_A(a^*)] = s + (1-\tau)ba^* - \frac{r\sigma_\varepsilon^2}{2}(1-\tau)^2 b^2 - c(a^*) \geqslant \widehat{u},$$
$$a^* \in \arg\max_{a\geq 0} \geq E[U_A].$$

The first constraint is the participation constraint (PC), which guarantees that the agent receives at least his reservation utility $\widehat{u}$. The second constraint represents the incentive compatibility constraint (IC) derived from the agent's maximization problem. The principal is able to control the agent's effort a by choosing an appropriate bonus rate b. Therefore, instead of replacing a, we use the IC and replace b with $c'(a)/(1-\tau)$ to set up the associated Lagrangian $\mathcal{L}_P$. Then, the Lagrangian with multiplier λ is given by

$$\mathcal{L}_P(a,s,\lambda) \equiv a - \frac{ac'(a)}{1-\tau} - s + \lambda\left(s + c'(a)a - \frac{r\sigma_\varepsilon^2}{2}c'(a)^2 - c(a) - \widehat{u}\right).$$

The corresponding first-order conditions are

$$\frac{\partial \mathcal{L}_P}{\partial a} = 1 - \frac{c'(a^*)}{1-\tau} - \frac{c''(a^*)}{1-\tau}a^* + \lambda\left[c''(a^*)a^* - c'(a^*)c''(a^*)r\sigma_\varepsilon^2\right] = 0,$$
$$\frac{\partial \mathcal{L}_P}{\partial s} = -1 + \lambda = 0,\ \frac{\partial \mathcal{L}_P}{\partial \lambda} = s + c'(a^*)a^* - \frac{r\sigma_\varepsilon^2}{2}c'(a^*)^2 - c(a^*) - \widehat{u} = 0.$$

Note that the principal has an incentive to provide a compensation package so that the PC is binding, i.e., the agent receives exactly his reservation utility $\widehat{u}$. Therefore, the derivative of $\mathcal{L}_P$ with respect to λ equals zero. With the above system, the agent's optimality condition $c'(a^*) = (1-\tau)b^*$ and $\lambda = 1$, we can rearrange the first-order condition of the principal and obtain[9]

$$1 = \underbrace{\left(b^* + \frac{\tau}{1-\tau}c''(a^*)a^*\right)}_{\text{leakage effect}} + \underbrace{r\sigma_\varepsilon^2(1-\tau)b^*c''(a^*)}_{\text{risk effect}}. \tag{2.2}$$

[8]We implicitely assume that, e.g., the outside option $\widehat{u}$ and the bonus tax τ are sufficiently small so that the principal obtains non-negative equilibrium profits.

[9]As shown in Appendix A.1, the second-order condition for a maximum is satisfied if $c'''(a^*) \geq 0$.

Equation (2.2) has an intuitive interpretation. A one-unit increase in the agent's effort (induced by a higher bonus rate) produces one-to-one higher expected revenue yielding a marginal revenue of one (lhs). The marginal revenue must be equal to the sum of the *leakage effect* (first term on rhs) and the *risk effect* (second term on rhs).[10] The former effect reflects the leakage in the contracting environment created through the bonus tax: the principal incurs the full cost of the bonus payment, while the agent receives only fraction $1-\tau$ of it. Recall that the state keeps fraction τ of the bonus payment. The leakage effect makes the use of bonuses more costly for the principal and is composed of two parts: (i) On the one hand, higher effort generates higher costs for the principal, given by $b^* + c''(a^*)a^*/(1-\tau)$, as she must pay the agent a higher bonus and incurs the full cost of the bonus payment.[11] (ii) On the other hand, higher effort induces an income effect $-c''(a^*)a^*$ for the agent so that the PC is relaxed. This income effect takes into account that the agent receives only fraction $1-\tau$ of the bonus payment. Combining (i) and (ii) yields the leakage effect.

The risk effect indicates that higher effort implies higher uncertainty for the agent regarding his expected salary because the salary variance increases so that the PC is tightened. It follows that the principal has to compensate the agent with a larger risk premium to accept the higher risk. It is important to mention that a higher degree of risk aversion of the agent and/or a larger variance in the firm value strengthen the risk effect because the risk premium increases. As we will see below, the risk effect plays a crucial role and may lead to counter-intuitive results regarding the effect of a bonus tax.

The next proposition establishes the existence and uniqueness of the equilibrium and presents the optimality conditions deduced from the first-order conditions of the agent and the principal.

Proposition 2.1.
(i) The equilibrium (b^*, s^*, a^*) exists and is unique.
(ii) The principal sets the optimal compensation package (b^*, s^*) as

$$b^* = \frac{(1-\tau) - a^* c''(a^*)\tau}{(1-\tau)\left[1 + (1-\tau)c''(a^*) r \sigma_\varepsilon^2\right]} \text{ and } s^* = \widehat{u} - c'(a^*)a^* + \frac{c'(a^*)^2}{2} r \sigma_\varepsilon^2 + c(a^*). \quad (2.3)$$

(iii) The agent exerts optimal effort a^* according to

$$c'(a^*) = (1-\tau)b^*. \quad (2.4)$$

Proof. See Appendix A.1. □

According to Proposition 2.1, a unique equilibrium exists for a general cost function that satisfies Assumption (A 2.1). The optimal bonus rate b^*, the optimal fixed salary s^*, and the optimal effort level a^* in equilibrium are defined implicitly by equations (2.3) and (2.4). The proposition further shows that the bonus rate b^* in equilibrium depends on the agent's degree of risk aversion r, the variance in the firm value σ_ε^2, the curvature of the agent's effort cost $c''(a^*)$, the bonus tax τ and the agent's equilibrium effort a^*.

[10] We are grateful to an anonymous referee who pointed out the leakage effect.

[11] The first term represents the higher bonus paid by the principal, induced by a one-unit increase in the agent's effort and the second term reflects the effort-induced effect on the bonus rate.

2.3.3 Effects of a Bonus Tax

In this section, we analyze how a bonus tax τ affects the agent's effort level a^*, the bonus rate b^*, and the fixed salary s^* in equilibrium. For notational simplicity, henceforth the parameter ρ stands for the product of the agent's level of risk aversion r and the variance in the firm value σ_ε^2, i.e., $\rho \equiv r\sigma_\varepsilon^2$. We refer to ρ as the "risk parameter" and establish the following proposition:[12]

Proposition 2.2. *A higher bonus tax τ has the following effects in equilibrium:*
(i) The agent unambiguously reduces his effort, i.e., $\frac{da^*}{d\tau} < 0$.
(ii) The principal increases (decreases) the bonus rate b^* if the risk parameter is larger (lower) than ρ_b, i.e.,

$$\frac{db^*}{d\tau} \gtreqless 0 \Leftrightarrow \rho \gtreqless \rho_b \equiv \frac{c''(a^*)(1-(1+\tau)b^* + c''(a^*)a^*) - \tau b^* c'''(a^*)a^*}{c'(a^*)\left[2c''(a^*)^2 + c'(a^*)c'''(a^*)\right]}.$$

(iii) The principal decreases (increases) the fixed salary s^* if the risk parameter is larger (lower) than ρ_s, i.e.,

$$\frac{ds^*}{d\tau} \lesseqgtr 0 \Leftrightarrow \rho \gtreqless \rho_s \equiv \frac{a^*}{c'(a^*)}.$$

Proof. See Appendix A.2. □

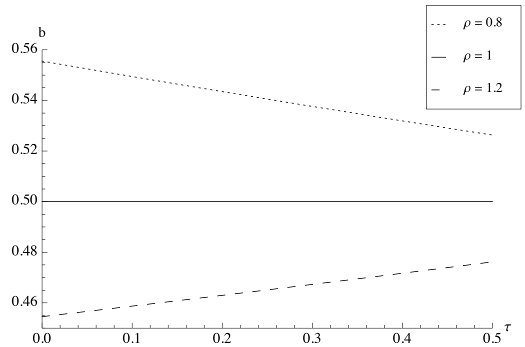
To highlight the results from Proposition 2.2, we provide Example 2.1 and illustrate the results in Figure 2.1.

Example 2.1. *Suppose that $c(a) = (\phi/2)a^2$.[13] We set $\phi = 1$, $\widehat{u} = 0.1$ and restrict the range of bonus taxes to the interval $\tau \in [0, 0.5]$ for which the principal's profits are non-negative. Note that the thresholds for the risk parameter in Proposition 2.2 are given by $\rho_b = \rho_s = 1$. Figure 2.1 depicts the bonus rate in Panel A, the fixed salary in Panel B and the agent's effort in Panel C on the y-axis as functions of the bonus tax on the x-axis for different risk parameters ρ.[14] We choose $\rho \in \{0.8, 1, 1.2\}$ to highlight the different cases in Proposition 2.2. Panel A shows that a higher bonus tax increases (decreases) the bonus rate if the risk parameter is larger (lower) than 1. The opposite is true with respect to the fixed salary (Panel B). If the risk parameter is equal to 1, then a bonus tax has neither an effect on the fixed salary nor on the bonus rate. Panel C shows that the agent's effort unambiguously decreases with a higher bonus tax.*

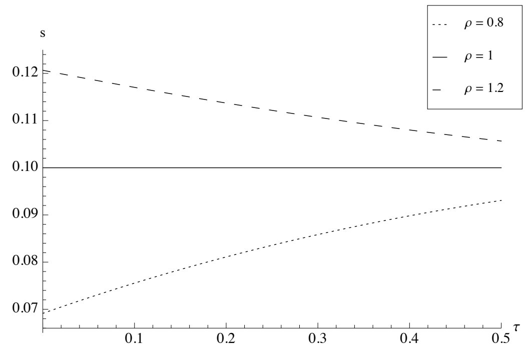
[12] Note that in the case of an endogenously-determined outside option $\widehat{u}(\tau)$, which negatively depends on τ, the results of Proposition 2.2 remain unchanged except for the effect of a bonus tax on the fixed salary s^*. In this case, only the condition in part (iii) changes to $\frac{ds^*}{d\tau} = \frac{d\widehat{u}(\tau)}{d\tau} + \frac{da^*}{d\tau}c''(a^*)\left[\rho c'(a^*) - a^*\right] \gtreqless 0$.

[13] Note that this function satisfies Assumption (A 2.1) and has well-defined properties that allow us to calculate the equilibrium values (a^*, b^*, s^*) in closed form.

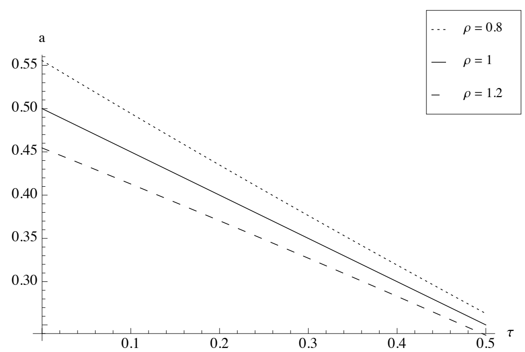
[14] Panel D depicts the agent's net-of-tax salary, which will be discussed below.



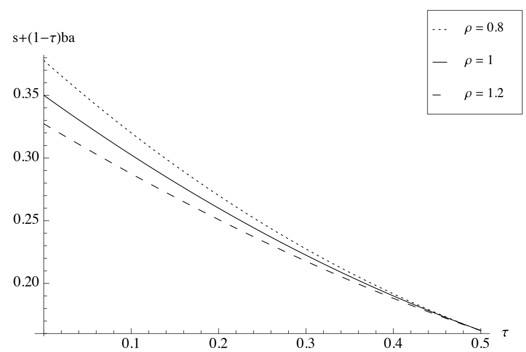
(A) Effect on Bonus Rate



(B) Effect on Fixed Salary



(C) Effect on Effort



(D) Effect on Net-of-tax Salary

Figure 2.1: Bonus Tax Effects for Quadratic Cost Functions

Now, we return to the case of a general cost function and provide the intuition for the results of Proposition 2.2. According to part (i), the agent unambiguously reduces effort as a reaction to a higher bonus tax. Recall from the optimality condition that the agent chooses effort so that the marginal effort costs equal the marginal benefit of effort in equilibrium, i.e., $c'(a^*) = (1-\tau)b^*$. The direct tax effect $(1-\tau)$ has a negative effect on the marginal benefit of effort (rhs). Based on part (ii) of Proposition 2.2, we know that b^* decreases in τ if $\rho < \rho_b$, which further reduces the marginal benefit. It follows that the marginal benefit unambiguously decreases if the bonus tax increases. In this case, it is clear that the agent reduces his effort in equilibrium. If $\rho > \rho_b$, then the bonus rate b^* increases through a higher bonus tax, which results in a positive effect on the marginal benefit of effort. However, the direct tax effect always overcompensates for a higher b^* so that the marginal benefit still decreases. Also in this case, the agent will reduce his effort in equilibrium.

Parts (ii) and (iii) show that, contrary to its intention, a bonus tax can induce the principal to set a higher bonus rate and a lower fixed salary. Particularly, the reaction of the principal to a higher bonus tax crucially depends on the variance in the firm value and how risk averse the agent is. If the corresponding risk parameter is sufficiently large (i.e., $\rho > \rho_b$), then a higher bonus tax leads to a higher bonus rate and thus increases the incentive power of the contract. Yet, if ρ is larger than another threshold (i.e., $\rho > \rho_s$), then a higher bonus tax leads to a lower fixed salary.[15]

The intuition for the effect on the bonus rate is as follows. From the principal's first-order condition in equation (2.2), we deduce that a higher bonus tax does not influence the principal's marginal revenue; the marginal revenue of effort is constant and equals one (lhs). However, a bonus tax influences the leakage and risk effects (rhs). On the one hand, a higher bonus tax strengthens the leakage effect because the agent receives a lower fraction of the bonus paid by the principal. As a consequence, the principal has incentives to reduce the bonus rate. On the other hand, a higher bonus tax decreases the risk premium required to compensate the agent for the uncertainty in his expected salary due to a lower salary variance. It follows that the principal has incentives to increase the bonus rate. Hence, the leakage effect induces the principal to decrease the bonus rate, while the risk effect provides incentives to increase the bonus rate. Whether the bonus rate increases or decreases through the introduction of a bonus tax depends on the relative size of these two effects. Because a higher risk parameter ρ has no direct influence on the leakage effect but it increases the risk premium and therefore strengthens the risk effect, the risk effect will dominate the leakage effect if ρ is sufficiently large (i.e., $\rho > \rho_b$). In this case a higher bonus tax induces the principal to increase the bonus rate b^*. If, however, $\rho < \rho_b$, then the principal decreases the bonus rate b^* through a higher bonus tax because the leakage effect dominates the risk effect. If $\rho = \rho_b$, then the leakage and risk effects balance each other out so that b^* is not affected by a change in the bonus tax.

In a next step, we provide the intuition for the principal's behavior with respect to the fixed salary s^*. The partial derivative of s^* with respect to τ is given by

$$\frac{ds^*}{d\tau} = [\underbrace{c''(a^*)a^*}_{\text{income effect}} - \underbrace{\rho(1-\tau)b^*c''(a^*)}_{\text{risk effect}}]\ \underbrace{\left(-\frac{da^*}{d\tau}\right)}_{>0}.$$

From the discussion regarding equation (2.2), we know that the income effect relaxes and the risk effect tightens the PC. We derive the following effects of a higher bonus tax. On the one hand, a higher tax diminishes the income effect because the agent receives a lower fraction of the bonus payment, and hence, the principal must increase the fixed salary to satisfy the PC. On the other hand, a higher tax lowers the salary variance in the agent's salary yielding a lower risk premium. In this case, the principal can decrease the fixed salary to satisfy the PC. Similar to above, the risk parameter influences the magnitude of the risk effect and therefore determines how bonus taxes affect the fixed salary. If $\rho > \rho_s$, then the risk effect dominates the income effect so that the principal has an incentive to decrease the fixed salary in equilibrium: that is, $\frac{ds^*}{d\tau} < 0$. The opposite holds true if $\rho < \rho_s$. In this case, the income effect dominates the risk effect and the principal increases the fixed

[15] It should be noted that the bonus rate b^* and the fixed salary s^* depend on the risk parameter so that the threshold values ρ_b and ρ_s themselves depend on ρ.

salary: that is, $\frac{ds^*}{d\tau} > 0$. Note that if $\rho = \rho_s$, then both effects are equally strong and s^* is not affected by a change in τ.

Based on parts (ii) and (iii) of Proposition 2.2, we can derive the following corollary:

Corollary 2.1. *The introduction of a bonus tax does not necessarily imply a substitution effect between the fixed salary s^* and the bonus rate b^*.*

Basic intuition might suggest that a bonus tax induces a substitution between the fixed salary and the bonus rate. However, such a substitution effect is not guaranteed because the threshold values ρ_s and ρ_b are not necessarily equal for a general cost function. For example, a higher bonus tax can induce a simultaneous increase in the fixed salary and the bonus rate. Such a pattern can occur, e.g., in the case of a cubic cost function.[16] However, for a quadratic cost function, the threshold values ρ_s and ρ_b are equal. In this case, a substitution effect is present between s^* and b^*, i.e., whenever a tax change induces the principal to increase the bonus rate, she will lower the fixed salary and vice versa.

In the next proposition, we analyze how a bonus tax affects the expected bonus payment and the expected salary in the case of a quadratic effort cost function $c(a) = (\phi/2)a^2$.

Proposition 2.3. *For a quadratic cost function, a higher bonus tax τ has the following effects in equilibrium:*
(i) The expected bonus payment b^*a^* given by the principal increases until the maximum is reached for a bonus tax given by $\tau' \equiv \frac{\rho\phi-3}{\rho\phi-1}$ if $\rho \in (\frac{3}{\phi}, \frac{5-\tau}{\phi(1-\tau)})$. However, the agent unambiguously receives a lower expected bonus payment $(1-\tau)b^*a^*$.
(ii) The expected gross salary $s^* + b^*a^*$ paid by the principal and the expected net-of-tax salary $s^* + (1-\tau)b^*a^*$ received by the agent unambiguously decrease.

Proof. See Appendix A.3. ☐

Part (i) of the proposition posits that the bonus paid by the principal can increase if these payments are taxed. This surprising result emerges if the risk parameter is sufficiently large (i.e., $\rho > 3/\phi$). Recall that the agent always reduces effort a^* with a higher bonus tax and that the principal's reaction depends on ρ.[17] It is clear that the bonus payment cannot increase if $\rho < 1/\phi$, because then, the principal also decreases the bonus rate b^*. Hence, a necessary condition to obtain an increase in the bonus payment with a higher tax rate is $\rho > 1/\phi$. According to Proposition 2.3, the threshold value of the risk parameter above which the bonus payment increases with the introduction of a bonus tax is given by $\rho = 3/\phi$. That is, only if $\rho > 3/\phi$ will the increase in the bonus rate compensate for the decrease in the agent's effort level. In this case, the bonus payment increases with a higher tax until the maximum is reached for $\tau = \tau'$. Raising the bonus tax above τ' decreases the bonus payment so that it can be even lower than in the benchmark case without a tax. As the state keeps τb^*a^*, the agent only receives $(1-\tau)b^*a^*$, which is always lower than without a tax. That is, the tax-induced decrease in $(1-\tau)$ always compensates for a potential increase in the bonus payment.

[16]Detailed simulation results for different cost functions are available upon request.
[17]Note that the thresholds ρ_s and ρ_b are given by $\rho_s = \rho_b = 1/\phi$ for $c(a) = (\phi/2)a^2$.

Part (ii) examines how a bonus tax affects the agent's salary.[18] We find that a bonus tax unambiguously induces a decrease in the gross salary, and consequently, also in the net-of-tax salary. Hence, a bonus tax is an effective policy instrument in reducing the agent's (gross and net-of-tax) salary. The intuition regarding the effect on the gross salary is as follows. If $\rho < 1/\phi$, then the increase in the fixed salary s^* cannot compensate for the decrease in the bonus payment b^*a^*. If $\rho \in (1/\phi, 3/\phi)$ both the fixed salary and the bonus payment decrease and if $\rho > 3/\phi$, then the decrease in the fixed salary outweighs the increase in the bonus payment so that the agent's gross salary unambiguously decreases independent of the risk parameter. It immediately follows that also the net-of-tax salary decreases. See Panel D of Figure 2.1, which depicts the agent's net-of-tax salary (y-axis) as a function of the bonus tax (x-axis) for different risk parameters.

It should be noted that the risk parameter influences how strong the salary decreases with a higher bonus tax. For example, a lower degree of risk aversion on the part of the agent and/or a lower variance in the firm value engender a stronger decrease in the agent's gross salary.

2.4 Conclusion

This essay has investigated the consequences of taxing the agent's bonus in a principal-agent model. A bonus tax has different effects on the fixed salary and the bonus rate because the principal sets an optimal compensation package on the conditions that the agent reaches at least his reservation utility and the package is incentive compatible. To determine the composition of the package, the principal anticipates that a higher bonus tax will increase the leakage in the contracting environment because the principal incurs the full cost of the bonus payment, while the agent receives only a fraction of it. This leakage effect makes the use of bonuses more costly for the principal. However, a higher bonus tax decreases the risk premium required to compensate the agent for the uncertainty in his expected salary due to a lower salary variance. This risk effect provides the principal with incentives to increase the bonus rate. Whether the bonus rate increases or decreases through the introduction of bonus taxes depends on the relative size of these two effects. Our model further shows that a bonus tax does not necessarily induce the principal to substitute variable salary with fixed salary for a general effort cost function. In particular, it is possible that a higher bonus tax simultaneously increases the fixed salary component and the bonus rate.

Moreover, we derive that the agent unambiguously reacts to a higher bonus tax with lower effort. For quadratic effort costs, despite a tax-induced effort reduction, a higher bonus tax induces the principal to pay higher bonuses if the agent is sufficiently risk averse and/or the variance in the firm value is sufficiently large. In this case, the increase in the bonus rate overcompensates for the decrease in the agent's effort. Therefore, it is not guaranteed that firms will have to pay lower bonuses after implementing a bonus tax. Nevertheless, a bonus tax reduces the overall salary of the agent so that a bonus tax proves to be an effective policy instrument in reducing the agent's salary. Hereby, the reduction of the

[18] We are grateful to an anonymous referee who suggested to analyze the overall salary.

agent's salary is more pronounced the lower the risk parameter.

To sum up, a bonus tax influences both the overall size and the structure of the agent's salary. For example, if the agent is highly risk averse, then the reduction in the agent's gross salary induced by a bonus tax is relatively small and, in addition, the principal shifts the compensation package from the fixed salary to the variable salary. However, if the agent is not too risk averse, then a bonus tax induces a relatively large reduction in the gross salary and also shifts the compensation package towards the fixed salary.

Our model yields potentially testable comparative-static results. In particular, our model might help to predict the sectors and firms in which bonuses would decrease or increase. In uncertain economic environments and/or in firms, in which the monitoring and evaluation of the manager's performance is comparatively hard, we expect that bonus taxes will induce a firm to pay higher bonuses. Additionally, we do not expect bonus tax to have the effect of shifting the bonus rate towards a fixed salary. That is, we anticipate low fixed salaries and high bonus rates. Moreover, our model predicts that the overall salary will only experience a relatively small reduction. We can derive the following examples of firms for these predictions: (i) New-economy firms: These firms tend to operate in more uncertain economic environments than old-economy firms. In addition, it might be more difficult to observe the manager's marginal contribution in new-economy firms because these firms grow faster, are more R&D intensive and have larger market-to-book ratios than old-economy firms (see Ittner, Lambert, and Larcker, 2003) (ii) Large firms: According to Schaefer (1998), large firms have more noisy measures of individual performance than small firms. Moreover, in large firms, one manager's action has less influence on the firm value than it might have in small firms. (iii) Privately held firms: Marino and Zábojník (2008) suggest that it is harder for privately held firms to evaluate their managers because a public firm's stock price provides an informative measure of performance which is less available in privately held firms.

Our simple model may serve as a basic framework to further analyze bonus taxes in a principal-agent model. There is a broad range of further applications and model extensions. For instance, an interesting avenue for further research could be the extension of our model to more than one period. An agent's effort decisions are often connected over time, and working contracts extend over several time periods. The implementation of these dynamics in the model could shed more light on the impact of bonus taxes on executive pay. Furthermore, an interesting extension would be to analyze the effects of bonus taxes on executives' risk-taking behavior or welfare implications of bonus taxes.

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Appendix A

A.1 Proof of Proposition 2.1

First, we compute the condition under which the principal's second-order condition is satisfied. The first-order condition of the principal can be written as

$$1-\gamma^{*}-\frac{c''(a^{*})}{1-\tau}a^{*}+c''(a^{*})a^{*}-(1-\tau)\gamma^{*}c''(a^{*})r\sigma_{\varepsilon}^{2}=0.$$

To ensure that the second-order condition for a maximum is satisfied, a lower bound of the third-order derivative of the cost function is required at a^{*}, i.e.,

$$c'''(a^{*})\geq\Psi^{*}\equiv-c''(a^{*})\frac{1+\tau+(1-\tau)c''(a^{*})r\sigma_{\varepsilon}^{2}}{a^{*}\tau+(1-\tau)c'(a^{*})r\sigma_{\varepsilon}^{2}}.$$

This inequality is satisfied because we assumed that $c'''(a)\geq 0$ for $a\geq 0$.

Second, we derive the optimality conditions. By solving equation (2.2), we obtain the optimal bonus rate b^{*} as

$$b^{*}=\frac{(1-\tau)-a^{*}c''(a^{*})\tau}{(1-\tau)\left[1+(1-\tau)c''(a^{*})r\sigma_{\varepsilon}^{2}\right]}. \tag{A.5}$$

With the binding PC, we calculate the optimal fixed salary s^{*} as

$$s^{*}=\widehat{u}-c'(a^{*})a^{*}+\frac{c'(a^{*})^{2}}{2}r\sigma_{\varepsilon}^{2}+c(a^{*}). \tag{A.6}$$

From (2.1), it is straightforward to derive the agent's optimality condition $c'(a^{*})=(1-\tau)b^{*}$.

Third, we show that the equilibrium (b^{*},s^{*},a^{*}) exists and is unique. By combining the two optimality conditions

$$c'(a)=(1-\tau)b \text{ and } b=\frac{(1-\tau)-ac''(a)\tau}{(1-\tau)\left[1+(1-\tau)c''(a)r\sigma_{\varepsilon}^{2}\right]},$$

we obtain

$$\underbrace{1-\tau}_{\equiv\kappa_{lhs}} \quad = \quad \underbrace{c'(a)+c''(a)(a\tau+(1-\tau)r\sigma_{\varepsilon}^{2}c'(a))}_{\equiv\kappa_{rhs}(a)}. \tag{A.7}$$

The left-hand side κ_{lhs} of equation (A.7) is independent of a and the right-hand side $\kappa_{rhs}(a)$ is a continuous function in a because the cost function satisfies Assumption (A 2.1). (i) For $a=0$, we obtain $\kappa_{lhs}=1-\tau>0=\kappa_{rhs}(0)$. (ii) For $a>0$, we derive

$$\frac{\partial\kappa_{rhs}(a)}{\partial a}>0\Leftrightarrow c'''(a)>\Psi(a)=-c''(a)\frac{1+\tau+(1-\tau)c''(a)r\sigma_{\varepsilon}^{2}}{a\tau+(1-\tau)c'(a)r\sigma_{\varepsilon}^{2}}.$$

Because $\Psi(a) < 0$ for $a > 0$ and according to Assumption (A 2.1), $c'''(a) \geq 0$, we conclude that $\frac{\partial \kappa_{rhs}(a)}{\partial a} > 0$. Thus, $\kappa_{rhs}(a)$ is a monotonically increasing function in a. Combining (i) and (ii) and using the assumption $\lim_{a\to\infty} c'(a) = \infty$, it is guaranteed that $\kappa_{rhs}(a)$ passes the constant κ_{lhs} for a certain effort $a = a^* > 0$. Hence, there exist exactly one intersection, which defines the unique equilibrium a^*. Plugging a^* into equations (A.5) and (A.6) yields the other equilibrium values (b^*, s^*).

A.2 Proof of Proposition 2.2

To prove Parts (i) and (ii), we use the optimality conditions

$$c'(a^*) = (1-\tau)b^* \text{ and } b^* = \frac{(1-\tau) - a^* c''(a^*)\tau}{(1-\tau)\left[1 + (1-\tau)c''(a^*)\rho\right]},$$

rearrange them and obtain

$$\begin{aligned}
&g_1(a^*, b^*, \tau) := c'(a^*) - (1-\tau)b^* = 0, \\
&g_2(a^*, b^*, \tau) := (1-\tau) - a^* c''(a^*)\tau - (1-\tau)b^*\left[1 + (1-\tau)c''(a^*)\rho\right] = 0.
\end{aligned}$$

Next, we derive the total differential of $g_1(a^*, b^*, \tau) = 0$ and $g_2(a^*, b^*, \tau) = 0$:

$$\begin{aligned}
\frac{\partial g_1}{\partial a^*}da^* + \frac{\partial g_1}{\partial b^*}db^* + \frac{\partial g_1}{\partial \tau}d\tau = 0, \\
\frac{\partial g_2}{\partial a^*}da^* + \frac{\partial g_2}{\partial b^*}db^* + \frac{\partial g_2}{\partial \tau}d\tau = 0.
\end{aligned}$$

The total differential can also be written as

$$\begin{bmatrix} g_{1a} & g_{1b} \\ g_{2a} & g_{2b} \end{bmatrix} \begin{bmatrix} da^* \\ db^* \end{bmatrix} = \begin{bmatrix} -g_{1\tau} \\ -g_{2\tau} \end{bmatrix} d\tau, \tag{A.8}$$

where

$$\begin{aligned}
g_{1a} &= \frac{\partial g_1}{\partial a^*} = c''(a^*), g_{1b} = \frac{\partial g_1}{\partial b^*} = -(1-\tau), g_{1\tau} = \frac{\partial g_1}{\partial \tau} = b^*, \\
g_{2a} &= \frac{\partial g_2}{\partial a^*} = -\left[\tau c''(a^*) + c'''(a^*)(a^*\tau + (1-\tau)^2 b^* \rho)\right], \\
g_{2b} &= \frac{\partial g_2}{\partial b^*} = -(1-\tau)\left[1 + \rho(1-\tau)c''(a^*)\right], \\
g_{2\tau} &= \frac{\partial g_2}{\partial \tau} = b^* - 1 - c''(a^*)\left[a^* - 2b^*\rho(1-\tau)\right].
\end{aligned} \tag{A.9}$$

Applying Cramer's Rule to (A.8), we derive

$$\frac{da^*}{d\tau} = \frac{g_{1b}g_{2\tau} - g_{2b}g_{1\tau}}{g_{1a}g_{2b} - g_{1b}g_{2a}} \text{ and } \frac{db^*}{d\tau} = \frac{g_{2a}g_{1\tau} - g_{1a}g_{2\tau}}{g_{1a}g_{2b} - g_{1b}g_{2a}}. \tag{A.10}$$

Plugging (A.9) into (A.10), we obtain

$$\frac{da^*}{d\tau} = \frac{c''(a^*)\left[(1-\tau)b^*\rho - a^*\right] - 1}{\zeta},$$
$$\frac{db^*}{d\tau} = \frac{b^*(a^*\tau + \rho(1-\tau)^2 b^*)c'''(a^*) - c''(a^*)\left[1 - (1+\tau)b^* + (a^* - 2\rho(1-\tau)b^*)c''(a^*)\right]}{(1-\tau)\zeta},$$

with $\zeta \equiv c''(a^*)\left[1 + \tau + (1-\tau)c''(a^*)\rho\right] + c'''(a^*)\left[a^*\tau + (1-\tau)^2 b^*\rho\right]$. It follows that

$$\frac{db^*}{d\tau} = 0 \Leftrightarrow \rho = \rho_b \equiv \frac{c''(a^*)(1 - (1+\tau)b^* + c''(a^*)a^*) - \tau b^* c'''(a^*)a^*}{c'(a^*)\left[2c''(a^*)^2 + c'(a^*)c'''(a^*)\right]}.$$

It is straightforward to show that $\frac{d(db^*/d\tau)}{d\rho} > 0$, i.e., $\frac{db^*}{d\tau}$ is a monotonically increasing function in ρ. It follows that $\frac{db^*}{d\tau} \gtreqless 0 \Leftrightarrow \rho \gtreqless \rho_b$, which proves Part (ii) of the proposition.

Regarding the agent's optimal effort a^*, with $c'''(a^*) \geq 0$,

$$\frac{da^*}{d\tau} \gtreqless 0 \Leftrightarrow \rho \gtreqless \rho_a \equiv \frac{1 + c''(a^*)a^*}{c'(a^*)c''(a^*)}.$$

At first glance, given that the risk parameter is sufficiently large, i.e., $\rho > \rho_a$, it is possible that the agent exerts more effort in equilibrium if the bonus tax increases. However, we will provide a proof by contradiction to show that the agent always reduces his effort with a higher bonus tax. Suppose that $\frac{da^*}{d\tau} \geq 0$. This assumption directly implies that $\frac{db^*}{d\tau} > 0$ because $c'(a^*) = (1-\tau)b^*$.[19] By using the PC and the IC, we rearrange the principal's first-order condition and obtain[20]

$$1 - b^* = \underbrace{c''(a^*)}_{\text{not dec. in } \tau}\Bigg[\rho \underbrace{c'(a^*)}_{\text{not dec. in } \tau} + \underbrace{a^*}_{\text{not dec. in } \tau} \underbrace{\frac{\tau}{(1-\tau)}}_{\text{inc. in } \tau}\Bigg]. \tag{A.11}$$

Under the assumption $\frac{da^*}{d\tau} \geq 0$, the rhs of equation (A.11) increases with a higher bonus tax τ. It follows that b^* on the lhs, which is by definition in the interval $(0,1)$, must decrease (i.e., $\frac{db^*}{d\tau} < 0$) to guarantee also an increase of the lhs. This result, however, contradicts the assumption $\frac{da^*}{d\tau} \geq 0$, which implies $\frac{db^*}{d\tau} > 0$. Hence, our assumption was wrong and it must be the case that $\frac{da^*}{d\tau} < 0$. This proves Part (i) of the proposition.

Proof of part (iii). Based on the optimality condition regarding the fixed salary $s^* = \widehat{u} - c'(a^*)a^* + \frac{c'(a^*)^2}{2}\rho + c(a^*)$, we compute $\frac{ds^*}{d\tau} = \frac{da^*}{d\tau}c''(a^*)\left(\rho c'(a^*) - a^*\right)$. With $\frac{da^*}{d\tau} < 0$, we conclude $\frac{ds^*}{d\tau} \lesseqgtr 0 \Leftrightarrow \rho \gtreqless \rho_s \equiv \frac{a^*}{c'(a^*)}$. This proves Part (iii) and completes the proof of the proposition.

[19] A higher bonus tax decreases the rhs of this equation and a necessary condition to guarantee an increase of the lhs is $\frac{db^*}{d\tau} > 0$.

[20] See also the discussion after Proposition 2.2.

A.3 Proof of Proposition 2.3

For a quadratic cost function $c(a) = (\phi/2)a^2$, we compute the optimal compensation package (b^*, s^*) and effort a^* as

$$(b^*, s^*) = \left(\frac{1}{1+\tau+\rho\phi(1-\tau)}, \widehat{u} - \frac{(1-\rho\phi)(1-\tau)^2}{2\phi\left[1+\tau+\rho\phi(1-\tau)\right]^2}\right), a^* = \frac{1-\tau}{\phi\left[1+\tau+\rho\phi(1-\tau)\right]}.$$

Proof of part (i). The partial derivative of the expected bonus b^*a^* (paid by the principal) with respect to τ is given by

$$\frac{\partial(b^*a^*)}{\partial\tau} = \frac{\tau-3+\phi\rho(1-\tau)}{\phi\left[1+\tau+\phi\rho(1-\tau)\right]^3} = 0 \Leftrightarrow \tau = \tau' \equiv \frac{\rho\phi-3}{\rho\phi-1}.$$

If $\rho < 1/\phi$, then b^*a^* is a convex function in τ and has a minimum at $\tau = \tau'$. If $\rho \in (\frac{1}{\phi}, \frac{5-\tau}{\phi(1-\tau)})$, then b^*a^* is a concave function in τ and has a maximum at $\tau = \tau'$. Moreover, we derive that for $\rho \in (1/\phi, 3/\phi)$, the threshold τ' is negative and for $\rho < 1/\phi$ or $\rho > 3/\phi$, τ' is positive. It follows that ρ has to be in the interval $(\frac{3}{\phi}, \frac{5-\tau}{\phi(1-\tau)})$ to guarantee that the bonus paid by the principal increases with a higher bonus tax until the maximum is reached for $\tau = \tau'$. Moreover, the partial derivative of the expected bonus $(1-\tau)b^*a^*$ (received by the agent) with respect to τ is given by

$$\frac{\partial\left((1-\tau)\,b^*a^*\right)}{\partial\tau} = -\frac{4(1-\tau)}{\phi\left[1+\tau+\rho\phi(1-\tau)\right]^3} < 0.$$

Hence, the bonus received by the agent always decreases with a higher bonus tax.

Proof of part (ii). To show that the expected gross salary $s^* + b^*a^*$ and the net-of-tax salary $s^* + (1-\tau)b^*a^*$ decrease in τ, we compute

$$\frac{\partial\left(s^*+b^*a^*\right)}{\partial\tau} = -\frac{1}{\phi\left[1+\tau+\rho\phi(1-\tau)\right]^2} < 0,$$
$$\frac{\partial\left(s^*+(1-\tau)b^*a^*\right)}{\partial\tau} = -\frac{2(1+\rho\phi)(1-\tau)}{\phi\left[1+\tau+\rho\phi(1-\tau)\right]^3} < 0,$$

which proves the claim. Moreover, $\frac{\partial^2(s^*+b^*a^*)}{\partial\tau\partial\rho} = \frac{2(1-\tau)}{[1+\tau+\rho\phi(1-\tau)]^3} > 0$, which shows that the decrease in the gross salary is stronger the lower the risk parameter ρ.

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3

Technology and Market Structure in the Defender Model*

joint with Helmut M. Dietl and Christian Jaag

Abstract

This essay studies a more specific version of the defender model by explicitly modeling the cost associated with product attributes. Two firms compete in three dimensions: two quality attributes which impact fixed and variable costs and product pricing. We then derive the optimal market defense for various market and cost structures and apply these findings to the liberalized postal sector and to the telecommunications industry. Drawing insight from these two applications, we explain observed investment behaviors of firms in these markets. In the telecommunications industry, we establish a consistent theoretical explanation for the empirical evidence about the regulation/investment trade-off shown by Grajek and Röller (2012) and Briglauer, Ecker, and Gugler (2012).

3.1 Introduction

This essay studies a more specific version of the defender model pioneered by Hauser and Shugan (1983). Therefore, we explicitly modeling a firm's cost structure associated with product attributes. Market positioning of products has long been an intensely discussed topic in the economics and marketing literature. Until the early 80s, the literature mainly confronted the issue of optimal new brand positioning. Existing brands thus got an indicator

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of how a new brand might attack. The reverse question of how to optimally defend its market share and profit against an attack remained unanswered until Hauser and Shugan (1983). In their original paper “Defensive Marketing Strategies”, Hauser and Shugan introduced a model that went beyond the traditional analysis of offensive new-brand positioning by focusing on the defending rather than on the attacking brand (defender model). One of their basic observations was that in most markets incumbents react to competition by lowering prices. In some industries, however, established firms defend their profits against market entrants by increasing product prices. Hauser and Shugan (1983) explain these differences by heterogeneity in consumer tastes. Another key assumption of their model is the ’per-dollar’ measure of product utility. Instead of integrating prices as a separate dimension in a traditional perceptual map (e.g., Urban and Hauser, 1980; Hauser and Gaskin, 1984), they interpret each quality dimension in relation to the product’s price (cf. Hauser and Simmie, 1981).

The defender model develops qualitative normative implications that instruct how established firms should defend their profits when facing an attack by a new competitive product. Hauser and Shugan (1983) did not limit the scope of strategic instruments to the dimension of price. They allowed incumbents to react by adjusting distribution and awareness advertising expenditures, budgets for repositioning advertising, and product quality improvements. The main recommendations were that prices should be decreased in non-segmented markets and potentially increased in highly-segmented markets; distribution and awareness advertising expenditures should be decreased while budgets for repositioning advertising and product improvement away from the strengths of the new products should be increased.

The model and its results have since been verified empirically for several industries, such as food, software and pharmaceuticals (cf. Hauser and Gaskin, 1984; Kuester et al., 2001). While the defender model predicts the optimal direction of response, later empirical studies examined further aspects of defensive actions, such as the reaction speed and the intensity of reactions. MacMillan, McCaffery, and Van Wijk (1985) find that reaction speed increases in the threat posed by the attacker and decreases with the size of the defending brand.[1] A high reaction speed has been observed in markets with high growth rates and low switching costs, as seen in Bowmann and Gatignon (1995).

Other studies focus on the intensity of the defending brand’s reactions. These studies find that the intensity of reactions increases in the threat posed by the attacker and in market size and growth (cf. Heil and Walters, 1993; Shankar, 1999). The incumbent’s market dominance and the extent of the attacker’s investments have been identified as being negatively correlated to reaction intensity (e.g., Kalra, Rajiv, and Srinivasan, 1998). Kuester et al. (2001) summarize the most relevant studies in the field of defensive strategies: reaction speed and intensity are highest in highly concentrated and growing markets, while size and innovation capabilities of the attacking firm have negative effects on the defending firm’s reaction intensity. The empirical significance of the model is demonstrated by

[1] In some industries, a delayed reaction could also be explained by signaling motives (cf. Kalra, Rajiv, and Srinivasan, 1998)

Hauser and Gaskin (1984) and Shugan (1987) who apply the defender model to different markets. Shugan (1987, p. 14) concludes that the model fits well and provides potentially useful information and Hauser and Gaskin (1984, p. 347) posit that the defender model is an adequate representation of aggregate consumer response. Nevertheless, the success of each application highly depends on the choice of attributes (cf. Hauser and Shugan, 2008).

The original defender model is confined by the assumption that quality attributes are strict substitutes: they do not cause specific costs but are restricted to add up to a constant amount. The contribution of this essay is to give the original defender model more structure by explicitly modeling the cost associated with quality attributes. This allows us to derive optimal defending strategies depending on an industry specific market and cost structure. Furthermore, the derived model can be applied to the postal sector and the telecommunications industry.

For many years, the postal sector has relied on a reserved area (monopoly) to finance universal services obligations. Recently, first liberalization steps took place and competition started to emerge. The defender model suggests strategies for the incumbents and the entrants. It also instructs that policy makers must be aware of the market forces when liberalizing this sector. In order to ensure that people in rural and less populated areas will be served, the government must provide benefits to attract firms there.

In the telecommunications industry, our model explains why regulated network access might undermine investment incentives. To the best of our knowledge, our research is unique in addressing these questions through application of the defender model. Empirically, Grajek and Röller (2012) consider the inherent regulation/investment trade-off between access regulation and investment incentives with a data set that covers more than 70 fixed-line operators in 20 countries over 10 years. Briglauer, Ecker, and Gugler (2012) extract the determinants of Next Generation Access (NGA) deployment with data from the 27 European Union member states for the years 2005 to 2010. While these two articles provide empirical evidence of this trade-off, the defender model allows to prove it theoretically.[2]

This essay is arranged as follows. Section 3.2 describes the defender model with its main assumptions and notations. Section 3.3 summarizes the results. Section 3.4 highlights the results in the context of postal liberalization and regulated network access in the telecommunications industry. Section 3.5 discusses the main insights and conclusions.

3.2 Model

The model is based on the paper by Hauser and Shugan (1983). Products differ in regard to quality attributes and prices, respectively. They induce variable and fixed costs. Firms compete by choosing the product's quality attributes and by setting its price. The resulting position determines the firm's market shares. Let V_i and F_i be the two quantities of the product's quality attributes provided by firm i. The two quality attributes differ in their cost structure: V_i imposes variable and F_i imposes fixed costs. P_i is the price of the

[2] The two companion papers by Valletti and Cambini (2005) and by Cambini and Valletti (2003) provide insight into the change in investment incentives based on networks with different levels of quality.

products. Then, $\boldsymbol{\Omega_i} \equiv \{V_i, F_i, P_i\}$ is the product attributes' bundle offered by firm i and $\pi_i(m_i(\boldsymbol{\Omega_i}, \boldsymbol{\Omega_j}), \boldsymbol{\Omega_i}, \boldsymbol{\Omega_j})$ its profit. $m_i(\boldsymbol{\Omega_i}, \boldsymbol{\Omega_j})$ denotes firm i's market share which is based on firm i's and firm j's position.

We are interested in firm i's reactions to changes in firm j's product attributes. In order to evaluate firm i's optimal reactions $x \in \boldsymbol{\Omega_i}$ due to an attack by firm j's attribute $y \in \boldsymbol{\Omega_j}$, we calculate the first order conditions and derive the optimal values $\boldsymbol{\Omega_i^*}(\boldsymbol{\Omega_j}) \equiv \{V_i^*(\boldsymbol{\Omega_j}), F_i^*(\boldsymbol{\Omega_j}), P_i^*(\boldsymbol{\Omega_j})\}$.

Next, we establish the reaction functions based on the total derivatives of the first order conditions $\partial\pi_i/\partial x = 0$:

$$\frac{dx}{dy} = -\frac{\frac{\partial^2 \pi_i(.)}{\partial x \partial y}}{\frac{\partial^2 \pi_i(.)}{\partial x^2}}, \tag{3.1}$$

where $x \in \boldsymbol{\Omega_i^*}(\boldsymbol{\Omega_j})$ and $y \in \boldsymbol{\Omega_j}$. The second order derivatives $\partial^2\pi_i/\partial x^2$ have to be negative in order to accomplish a profit maximum at the corresponding positions. Therefore, the nominator in equation (3.1) defines the sign of dx/dy. We summarize this insight in the first lemma.

Lemma 3.1. *Firm i's reactions $x \in \boldsymbol{\Omega_i^*}(\boldsymbol{\Omega_j})$ to changes in firm j's attributes $y \in \boldsymbol{\Omega_j}$ are given by the signs of the mixed second order derivatives.*

$$\operatorname{sgn}\left[\frac{dx}{dy}\right] = \operatorname{sgn}\left[\frac{\partial^2 \pi_i(.)}{\partial x \partial y}\right]$$

Proof. Based on equation (3.1), the claim follows immediately. □

So far, we have introduced a general framework to tackle the research question. We must further specify the reduced-form profit function to establish more advanced results. Then, firm i's optimal reactions to attacks by firm j can be calculated and discussed. However, the assessment of the model requires more specifications. We use the definitions and assumptions from Hauser and Shugan (1983, pp. 321), namely representation by product position, utility maximization and linearity. Hence, the consumer model introduced below follows the main assumptions in the original defender model. Every customer in the market maximizes his or her utility u. Let u_i be the utility which a randomly selected customer places on the purchase of one unit of brand i. Each brand i's position is defined by the amount of attribute 1 obtainable from one unit V_i of brand i, and the amount of attribute 2 obtainable from one unit F_i of brand i. The utility a customer places on one unit of brand i is noted as $\tilde{u}_i$, which is a random variable to reflect customer heterogeneity. In a market with more than one brand available, the customer decides to purchase the brand closest to his or her preferences. The probability that a randomly chosen customer chooses brand i is denoted as m_i. It is defined as

$$m_i(\tilde{u}_i, \tilde{u}_j) \equiv Prob[\tilde{u}_i > \tilde{u}_j, \forall i \neq j],$$

where $Prob[.]$ denotes a probability function. To compute customer preferences, we follow the original defender model by defining $\tilde{w}_k$ as the weight a customer places on attribute k.

We refine the definition of m_i as

$$m_i(\boldsymbol{\Omega_i}, \boldsymbol{\Omega_j}) \equiv Prob\left[\frac{\tilde{w}_1 V_i + \tilde{w}_2 F_i}{P_i} > \frac{\tilde{w}_1 V_j + \tilde{w}_2 F_j}{P_j}\right]$$

or, after straightforward algebraic manipulations,

$$m_i(\boldsymbol{\Omega_i}, \boldsymbol{\Omega_j}) \equiv Prob\left[\left(\frac{V_i}{P_i} - \frac{V_j}{P_j}\right) > \frac{\tilde{w}_2}{\tilde{w}_1}\left(\frac{F_j}{P_j} - \frac{F_i}{P_i}\right)\right].$$

Hence, in a two-attribute space, the preferences of each customer can be represented by an indifference curve with angle $\tilde{w}_2/\tilde{w}_1$. The slope of the ray from the origin that intersects the indifference curve orthogonally is thus defined as $\tilde{\alpha} \equiv \tan^{-1}(\tilde{w}_2/\tilde{w}_1)$. Figure 3.1 geometrically illustrates a randomly chosen customer's preferences. Any customer will favor the brand that maximizes his or her utility. For the sake of simplicity, we assume customer preferences to be uniformly distributed.

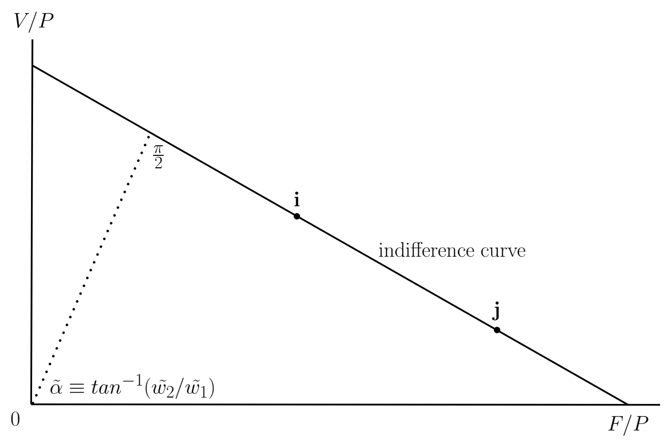

Figure 3.1: Geometric illustration of a randomly chosen customer's preferences

In the initial market equilibrium are two firms offering brand i and brand j. Each brand's position in the two-attribute space is defined by its perceived attribute levels (V, F) and its unit price P. Given the first brand's position, the other firm will set its price adjusted quality attributes on the top left or bottom right, which correspond to one of the shaded areas in Figure 3.2. Hence, there is a restriction on the second brand's positioning,

$$\left(\frac{V_i}{P_i} - \frac{V_j}{P_j}\right)\left(\frac{F_i}{P_i} - \frac{F_j}{P_j}\right) \leq 0 \tag{3.2}$$

which implies that each of the two firms' products has a "strong" and a "weak" quality dimension.

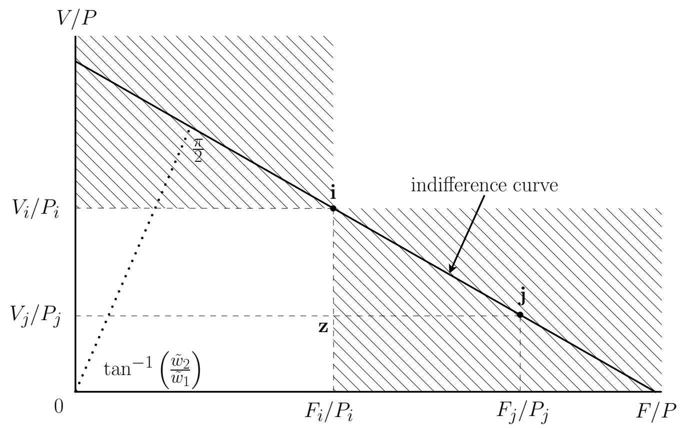

Figure 3.2: Positioning and Market Shares

Figure 3.2 illustrates a situation in which brand i is positioned in point i and brand j is positioned in point j. The straight line with slope $r = -(V_i/P_i - V_j/P_j)/(F_j/P_j - F_i/P_i) = -\overline{iz}/\overline{jz}$ thus represents the indifference curve of the customer that is precisely indifferent between brands i and j. All customers with a steeper indifference curve than the one shown will choose brand j those with a flatter indifference curve will choose brand i. Since we assume customer preferences to be uniformly distributed, the ray from the origin that orthogonally intersects this indifference curve now segregates the market in the shares obtained by brands i and j. Firm i's market share[3] is thus given as

$$m_i(\boldsymbol{\Omega_i}, \boldsymbol{\Omega_j}) = \begin{cases} \frac{2}{\pi}\arctan\left(\frac{\frac{V_i}{P_i}-\frac{V_j}{P_j}}{\frac{F_j}{P_j}-\frac{F_i}{P_i}}\right) & \text{if } \frac{V_i}{P_i}-\frac{V_j}{P_j} > 0 \\ 1-\frac{2}{\pi}\arctan\left(\frac{\frac{V_i}{P_i}-\frac{V_j}{P_j}}{\frac{F_j}{P_j}-\frac{F_i}{P_i}}\right) & \text{if } \frac{V_i}{P_i}-\frac{V_j}{P_j} \leq 0. \end{cases}$$

Total market size is assumed to be constant and equal to one. Hence, firm i's total sales volume is given as m_i.

Three conditions that must be satisfied to apply our model. First, the attributes must be relevant in that they affect the buying decisions of customers. Second, they are substitutive in nature.[4] This ensures that (a) no brand can have high characteristics in all attributes at the same time and (b) each brand has to be positioned efficiently (shaded area in Figure 3.2) because no customer will chose a brand that is inferior to another in all price adjusted attributes. Third, the attributes have to be measurable.

The production of a certain level of quality entails cost. We assume costs to be convex in quality and denote $C_1(m_i, V_i)$ as variable cost and $C_2(F_i)$ as fixed (volume independent)

[3]Note, the market share m_j can be computed as $m_j = 1 - m_i$.

[4]Hauser and Shugan (1983) chose the attributes efficacy and mildness for liquid dish washing detergents.

cost. Thus, firm i's profit is given as

$$\begin{aligned}\pi_i(\boldsymbol{\Omega_i},\boldsymbol{\Omega_j}) &= R\big(m_i(\boldsymbol{\Omega_i},\boldsymbol{\Omega_j}),P_i\big) - C_1\big(m_i(\boldsymbol{\Omega_i},\boldsymbol{\Omega_j}),V_i\big) - C_2(F_i)\\ &= m_i(\boldsymbol{\Omega_i},\boldsymbol{\Omega_j})\left(P_i - gV_i^d\right) - fF_i^b,\quad i\neq j,\end{aligned}\tag{3.3}$$

where $0 \leq V_z \leq 1$ and $0 \leq F_z \leq 1$, $z \in \{i,j\}$. Parameters f and g govern the absolute cost levels associated with the choices of V_i and F_i, while $b,d > 1$ determine the convexity of the cost functions.[5] We will denote the markup as $\mu_i \equiv P_i - gV_i^d$. It is the gross profit per unit since gV_i^d depicts the variable costs.

Firm i optimizes its two quality attributes and its price according to its first order conditions. Therefore, it sets its attributes by analyzing the marginal effect between revenue and cost. Changes in market share affect revenue as well as variable costs. We will discuss firm i's reaction functions hereafter in reference to a *markup*- and a *quantity*-effect.

3.3 Results

Based on the model framework introduced in Section 3.2, we will work out firm i's optimal reactions. This also reveals with which attributes firm j attacks most efficiently.

The following notations are required to read the results below correctly. Firm i provides a high variable cost and a low fixed cost attribute in relation to firm j, if it is positioned at the top left (strong in V_i) and the reverse at the bottom right (see Figure 3.2).[6] Furthermore, firm i is denoted with subscript D (Defender) and firm j with subscript A (Attacker).

In Lemma 3.1 we have shown that the second order derivative of firm D is necessary in order to find its optimal reaction behavior. Thus, based on the profit function (3.3) results

$$\frac{\partial^2 \pi_D(\boldsymbol{\Omega_D},\boldsymbol{\Omega_A})}{\partial x \partial y} = \frac{\partial^2 m_D}{\partial x \partial y}\mu_D + \frac{\partial m_D}{\partial y}\frac{\partial \mu_D}{\partial x},$$

with $x \in \boldsymbol{\Omega_D}$, $y \in \boldsymbol{\Omega_A}$ and $\mu_D \equiv P_D - gV_D^d$. The expression on the right hand side (rhs) of the equation corresponds to the marginal change in net profit of firm D if attacked by firm A. Specifically, firm D reacts to an attack with a profit maximizing adjustment of its attributes. Hence, the analysis of an attack by firm A can be divided into two types of effects.

Definition 3.1 (Quantity-Effect). *Describes the change in the effect which x has on m_D due to a change in attribute y. Formally it is written as*

$$\frac{\partial^2 m_D}{\partial x \partial y}\mu_D,\ x \in \boldsymbol{\Omega_D},\ y \in \boldsymbol{\Omega_A}.$$

The second effect of firm D relates to its markup. It adjusts the marginal markup to address an attack by firm A.

[5] The first order and the second order conditions of the profit function are derived in Appendices B.1 and B.2.

[6] In practice, most incumbents in post markets or network industries are positioned at the bottom right.

Definition 3.2 (Markup-Effect). *Describes the change in the effect which y has on m_D due to the effect which x has on μ_D. Formally it is written as*

$$\frac{\partial m_D}{\partial y}\frac{\partial \mu_D}{\partial x}, x \in \boldsymbol{\Omega_D}, y \in \boldsymbol{\Omega_A}.$$

Firm D's markup-effect vanishes if it is calculated in terms of the fixed cost attribute ($\partial\mu_D/\partial F_D = 0$).

Lemma 3.2. *Reactions to attacks on firm D's fixed cost attribute result in a quantity-effect only.*

Proof. Given the mixed second order derivative

$$\frac{\partial^2 \pi_D}{\partial x \partial y} = \frac{\partial^2 m_D}{\partial x \partial y} + \frac{\partial m_D}{\partial y}\frac{\partial (P_D - gV_D^d)}{\partial x}, \; x \in \boldsymbol{\Omega_D}, \; y \in \boldsymbol{\Omega_A}$$

with $x \in \boldsymbol{\Omega_D}$ and $y \in \boldsymbol{\Omega_A}$. Then, the markup-effect on the rhs will vanish for $x \equiv F_D$. This completes the proof. □

The results depend on the positions of the defending and the attacking firm. Therefore, we distinguish two cases. First, firm D is positioned at the top left of firm A. Second, the two firms are in reversed positions (see Figure 3.2).

To simplify the reading of the results, we mark quality attributes with an upper bar if firm D provides a higher price adjusted quantity than firm A and with a lower bar if it provides a lower price adjusted quantity, respectively. The three abbreviations "aggr.", "def." and "amb." denote firm D's behavior in terms of an attack by firm A. Aggressive behavior implies an increase in firm D's quality attributes or a decrease in its price. Therefore, defensive behavior by firm D has reverse impacts and the behavior is ambiguous if markup- and quantity-effects counteract each other. The threshold values $\tilde{m}_{i,j} = \tilde{m}_{j,i}$ denote the market share in the case of an attack on firm D's attribute i (j) with attribute j (i) of firm A. These thresholds exist and show a change in the sign of the quantity-effect. However, the entire impact of an attack can already change its sign before the threshold values are reached if the markup-effect outweighs the quantity-effect. Furthermore, we refer to the term "market dominance of firm D" if its market share is higher than firm A's market share and vice versa. We call an attribute weak (strong) provided if the price adjusted quantity of firm D is lower (higher) then the price adjusted quantity of firm A.

Yet, we have introduced the model and the necessary notations. By taking into account Lemma 3.2, we can establish the two following effect tables based on the firm's position.

Defending firm D is positioned at the Bottom Right

This section focuses on the case in which firm D is positioned at the bottom right in relation to firm A (see Figure 3.2), i.e., it provides a strong fixed cost and a weak variable cost attribute.

Table 3.1: Reactions of firm D if positioned at the bottom right of firm A

Firm D reacts with

Firm A attacks with	$\underline{V_D}$	$\overline{F_D}$	P_D
$\overline{V_A}$	amb.	$m_D > m_A \Rightarrow$def. $m_D < m_A \Rightarrow$aggr.	$m_D \geqslant \tilde{m}_{P,V} \Rightarrow$ aggr. $m_A \geqslant m_D \Rightarrow$ amb.
$\underline{F_A}$	$m_D > m_A \Rightarrow$amb. $m_D < m_A \Rightarrow$ aggr.	aggr.	$m_D \geqslant m_A \Rightarrow$aggr. $m_A \geqslant \tilde{m}_{P,F} \Rightarrow$amb.
P_A	$m_D \geqslant \tilde{m}_{V,P} \Rightarrow$aggr. $m_A \geqslant m_D \Rightarrow$amb.	$m_D \geqslant m_A \Rightarrow$aggr. $m_A \geqslant \tilde{m}_{F,P} \Rightarrow$def.	$m_D > 1 - \tilde{m}_{P,P} \Rightarrow$amb. $m_D < 1 - \tilde{m}_{P,P} \Rightarrow$aggr.

The following lemma states how firm D's reactions change if it alters its position in terms of firm A. Therefore, we take advantage of the *Schwarz Theorem* and separate the derivatives into the two effects in Definition 3.1 and 3.2.

Lemma 3.3. *The markup-effect is robust with respect to firm repositioning. The quantity-effect changes its sign from negative to positive and vice versa if firm D changes its position in terms of firm A.*

Proof. See Appendix B.6. □

The market share "stealing effect" — higher quality attributes or a lower price — remains after a firm repositioning has taken place. The quantity-effect on the other hand depends on the provided quantity of the price-adjusted attributes. Hence, it changes its sign whenever firms change their position. Formally, the two implications can be proved based on the relation $m_i = 1 - m_j$.

The impact of Lemma 3.3 is necessary to derive the results in which firm D alters its position in terms of firm A. Thus, the analysis recognizes the changing sign of the quantity-effect.

Defending firm D is positioned at the Top Left

This section focuses on the case in which firm D is positioned at the top left in relation to firm A (see Figure 3.2). Given this assumption, the following table summarizes firm D's reactions if attacked by firm A.

Table 3.2: Reactions of firm D if positioned at the top left of firm A

Firm A attacks with \ *Firm D reacts with*	$\overline{V_D}$	$\underline{F_D}$	P_D
$\underline{V_A}$	aggr.	$m_D > m_A \Rightarrow$ aggr. $m_D < m_A \Rightarrow$ def.	$m_D \geqslant m_A \Rightarrow$ aggr. $m_A \geqslant \tilde{m}_{P,V} \Rightarrow$ amb.
$\overline{F_A}$	$m_D > m_A \Rightarrow$ aggr. $m_D < m_A \Rightarrow$amb.	def.	$m_D \geqslant \tilde{m}_{P,F} \Rightarrow$ aggr. $m_D \leqslant m_A \Rightarrow$amb.
P_A	$m_D \geqslant m_A \Rightarrow$ aggr. $m_A \geqslant \tilde{m}_{V,P} \Rightarrow$amb.	$m_D \geqslant \tilde{m}_{F,P} \Rightarrow$aggr. $m_D \leqslant m_A \Rightarrow$def.	$m_D > \tilde{m}_{P,P} \Rightarrow$aggr. $m_D < \tilde{m}_{P,P} \Rightarrow$amb.

The two derived tables conclude all reactions of firm D if the two firm's position satisfies the restriction in inequality (3.2). Next, we summarize the impact of these two tables.

Proposition 3.1 (Attack with Variable Cost Attribute). *If firm A attacks with*

(i) its strong variable cost attribute, then,

- *firm D's reaction if attacked on its weak variable cost attribute is ambiguous.*
- *firm D reacts defensively with its strong fixed cost attribute if it dominates the market and it reacts aggressively otherwise.*
- *firm D reacts aggressively with its price if its market share exceeds a certain market share threshold or the markup-effect outweighs the quantity-effect.*

(ii) its weak variable cost attribute, then,

- *firm D reacts always aggressively with its strong variable cost attribute.*
- *firm D reacts aggressively with its weak fixed cost attribute if it dominates the market and defensively otherwise.*
- *firm D reacts aggressively with its price if it dominates the market.*

Proof. See Appendix B.3. ☐

Proposition 3.1 highlights that firm position matters. An attack as a market entrant ($m_A < m_D$) with a strong variable cost attribute will force the incumbent to cut its strong fixed cost attribute. Such a situation can be disadvantageous for both firms, for instance, if the entrant takes advantage of a network based on access regulation (see Section 3.4).

Firm D's reaction is ambiguous if the attack addresses its weak variable cost attribute. Therefore, the markup- and quantity-effects counteract each other. Furthermore, if firm D dominates the market significantly or the markup-effect outweighs the quantity-effect, it will also compete with a price cut to attack firm A's variable cost attribute.

The implications are different if, instead, the attacking firm provides a weak variable cost attribute. Then, the dominant firm D reacts with both attributes and price aggressively to attacks. As a result, the attacking firm has to expect hard competition with firm D.

Proposition 3.2 (Attack with Fixed Cost Attribute). *If firm A attacks with*

(i) its weak fixed cost attribute, then,

- *firm D's reaction with its weak variable cost attribute is ambiguous if it dominates the market. It reacts aggressively if firm A dominates the market.*
- *firm D reacts always aggressively with its strong fixed cost attribute.*
- *firm D reacts aggressively with its price if it dominates the market or the markup-effect outweighs the quantity-effect.*

(ii) its strong fixed cost attribute, then,

- *firm D reacts aggressively with its strong variable cost attribute if it dominates the market. Otherwise, firm D's behavior relies on the size of markup-effect and quantity-effect.*
- *firm D reacts always defensively if attacked on its weak fixed cost attribute.*
- *firm D reacts aggressively with respect to a price increase if its market share exceeds a certain threshold or the markup-effect outweighs the quantity-effect.*

Proof. See Appendix B.4. □

Proposition 3.2 confirms again, that firm D's position is crucial. Provided firm A attacks with its weak fixed cost attribute, then firm D will always compete with its strong fixed cost attribute. It also reacts aggressively with its price if it dominates the market. If firm D is attacked on its weak variable cost attribute and firm A dominates the market, firm D will increase its variable cost attribute. If firm D dominates the market, the reaction depends on the markup-effect and on the quantity-effect.

If firm A attacks with a strong fixed cost attribute and firm D dominates the market, then, firm A will be exposed to a higher competition in terms of the variable cost attribute. Firm D cuts its weak fixed cost attribute if attacked with the strong fixed cost attribute of firm A. Furthermore, firm D will react aggressively with its price if it dominates the market significantly or the markup-effect outweighs the quantity-effect.

Proposition 3.3 (Attack with Price). *If firm A attacks with a lower price, then,*

- *firm D reacts aggressively with its variable cost attribute if it dominates the market.*
- *firm D reacts aggressively with its fixed cost attribute if it dominates the market.*
- *firm D positioned at the bottom right reacts aggressively with its own price if its market share is lower than the threshold $1 - \tilde{m}_{P,P}$. It also reacts aggressively if it is positioned at the top left and its market share is higher than $\tilde{m}_{P,P}$. However, these two reactions also occur in any case if the markup-effect outweighs the quantity-effect.*

Proof. See Appendix B.5. □

Before analyzing the implications of Proposition 3.3, we must emphasize that price changes affect the relative size of the provided attributes as well. Apart from one exception, firm D always reacts aggressively with its attributes if attacked with firm A's price. Nonetheless, the reaction with regard to firm D's price is ambiguous if firm D is positioned at the bottom right. In this case, the markup-effect is positive whereas the quantity-effect is negative. But even in this case firm D will react aggressively if the markup-effect outweighs the quantity-effect. Firm A's entry into the market with a price attack might be hazardous unless it has already obtained a significant market share.

We will now apply these theoretical results to real-world examples.

3.4 Implications

Our modifications of the defender model can be applied to specific industries with particular cost structures and market share distributions. Most of the markets which recently moved towards liberalization (e.g., postal, electricity, telecommunications) provide straightforward applications for the case when firms with high fixed costs are attacked. It is more challenging to identify industries in which an incumbent provides a technology that imposes mainly variable costs. In such markets, potential competitors can enter with lower risk, hence, a higher degree of competition can be expected in these markets.

In what follows, we will discuss two real-world industries in which the incumbent operates with a high fixed cost technology and will be attacked by an entrant that provides a technology that mainly imposes variable costs. This corresponds to the situation in which firm D is positioned at the bottom right of firm A. Specifically, we will apply the defender model on the postal sector and on the telecommunications industry.

The postal sector has traditionally relied on a reserved area to finance universal service obligations. In recent years, it has been increasingly opened up to competition in many countries. There is limited literature on competitive entry strategies in postal markets. Based on a game-theory model and interviews with market participants, Dietl and Waller (2002) argue that competition in letter markets lead to new services and lower, but differentiated prices. While businesses and customers in urban areas will benefit from price decreases, households and rural areas will face higher prices. New business models such as mass mail providers, networked mail services, and consolidations with differentiated services will emerge, targeting selected segments of the market. Incumbents will have to significantly change their behavior, become more efficient, and tailor their services to individual needs. The interaction between competition and universal service regulation has been studied by Crew and Kleindorfer (2001, 2007). Dietl, Trinkner, and Bleisch (2005) and Jaag (2007) provide applications to the mail market in Switzerland. Kleindorfer and Szirmay (2009) review pricing practices of incumbent postal operators in Europe in the context of liberalization, but they also recognize the rudimentary state of applied marketing practices and capabilities.

In the European Union, member states must fully liberalize their postal markets by the year 2013. In 1993, Sweden was one of the first European countries to open their letter mail market. In 2013, Sweden Post still dominates the postal market. It offers a broad product range of services and delivers mail every business day countrywide. Bring CityMail is the only important competitor. It started operations in 1991 as an independent operator. Today, it is owned by Norway Post, the public operator of Norway. Bring CityMail only delivers electronically-generated bulk mail to Sweden's largest cities, i.e., to about 40 percent of all Swedish households. It delivers mail twice per week. Therefore, it only competes with economy bulk mail offered by Sweden Post. Hence, it has chosen a very selective market entry strategy by focusing on the most attractive (least cost) product segment and the most densely populated (again least cost) delivery areas.

Cohen et al. (2007) discuss the impact of competitive entries into the Swedish postal market. They find that almost immediately after Bring CityMail entered the market, Sweden Post began to adjust its pricing structure by introducing discounts for bulk and presorted mail. Its bulk mail prices have decreased, reflecting the intense competition from Bring CityMail, while the prices of uncontested single-piece items have increased. This behavior is consistent with the analysis of the defender model.

Jaag et al. (2012) apply a simple version of the defender model with two quality dimensions to the postal sector. They find that the incumbent is most effective if it reacts to the weak quality dimension. Hence, quality adjustment in this dimension dominates the reaction in price. By contrast, if an incumbent is relatively weak on the variable cost attribute, a low-price attack on this attribute harms the incumbent the most. However, it can be rendered less attractive to the attacker if an incumbent threatens to lower prices or strengthen its own product quality.

The theoretical defender model developed in this essay widely confirms these implications. Additionally, the results state that an entrant's attack with its strong variable cost attribute induces the incumbent to decrease its strong fixed cost attribute. That undermines the service provision of the less dense populated and rural areas. However, an attack with the entrant's fixed cost attribute encourages the incumbent to increase its fixed cost attribute as well. If either firm invests in their fixed cost attributes, competition will encourage the market participants to increase the attractiveness of their own fixed cost technology. Whether a price attack by the entrant tends to be successful depends on the quantity-effect and on the markup-effect and therefore on the specific market structure.

The defender model also helps explain observed investment behaviors in the telecommunications industry. Like the postal sector, the telecommunications industry is often comprised of a small number of market participants among which one used to be a government monopolist. Furthermore, incumbents need to invest significant capital to build and maintain their network.

Entrants have to make large up-front investments unless access regulation is provided. The construction of a network necessitates tremendous investment costs with no certainty regarding future events. Government intervention can mitigate these risks. For instance, the European Union opened telecommunications to competition by other retailers by unbundling elements of the incumbent's network. This intervention was justified by an expected increase in competition in the retail market and therefore lower prices which would create a higher consumer surplus. However, although access regulation might increase competition and lower prices, it might also undermine investment incentives over time.[7] Grajek and Röller (2012) name this relationship the “regulation/investment trade-off”.[8] With regulated access, entrants can rely on an existing network at mandated prices and they need not duplicate it.[9]

The controversial question whether access to networks should be provided or not has been intensively discussed in the literature. The contribution by Guthrie (2006) surveys the literature on the implications of different regulation schemes. In particular, it posits the relevance of modern investment theory, focusing on risk and intertemporal investment incentives. In a recent work, Hausman and Taylor (2012) discuss whether regulation in network markets is necessary at all and how high mandated access prices should be. Valletti (2003) highlights the linkage between access pricing and incentives to invest. Nitsche and Wiethaus (2011) examine to what extent different types of access regulation to Next Generation Networks affect investments and consumer welfare.

Stühmeier (2013) investigates incumbent’s and entrant’s advantages in the telecommunications industry based on two widely proposed regulatory regimes: a cost-based regulation and a reciprocal regulation. Incumbents enjoy a demand-side advantage whereas entrants may enjoy a supply-side advantage due to higher efficiency that bases on better opportunities to adapt new and innovative technologies. Gruber and Koutroumpis (2013) show that firm and intra-platform competition on the incumbent’s legacy network stimulates the adoption of broadband what they have not found for different access technologies. Their empirical evidence bases on data from 167 broadband markets over a period of 11 years. Grajek and Röller (2012) provide evidence for the regulation/investment trade-off by a data set which covers more than 70 fixed-line operators in 20 countries over 10 years. Briglauer, Ecker, and Gugler (2012) come up with another empirical study in which they extract the determinants of Next Generation Access (NGA) deployment with data from the 27 European Union member states for the years 2005 to 2010. They reveal with their study

[7] Gans and King (2004) discuss an approach to solve the truncation problem of risky investments. They establish conditions under which an access holiday (a fixed period free of regulated access) can improve investment incentives. Based on Next Generation Access Networks, Inderst and Peitz (2012) investigate the impact of different contract types and access regulation on innovation and competition in the telecommunications industry. They find that ex-post access contracts prevent a duplication of investment more often and lead to a wider roll-out compared with markets in which such contracts are not available. Ex-ante contracts on the other hand provide an even wider roll-out than ex-post contracts and lead to an even less frequent duplication of investments. Nonetheless, ex-ante and ex-post contracts can also be used to dampen competition.

[8] A special case of this trade-off is highlighted by the so-called ladder hypothesis of investment (Cave and Vogelsang 2003; Cave 2006a,b), also referred to as the stepping stone hypothesis by Rosston and Noll (2002). The ladder hypothesis states that easy access is needed to incentivize entries and higher infrastructure investments in the long run.

[9] Vogelsang (2003) presents a profound analysis of network access and interconnection with its underlying pricing method. Starting with the Baumwol-Willig efficient component pricing rule (ECPR), Armstrong, Doyle, and Vickers (1996) analyze the notion of the “opportunity cost” under various assumptions. They show that the Ramsey approach to access pricing is closely related to the ECPR provided the opportunity cost is correctly interpreted.

that stricter ex-ante broadband access regulation has a negative impact on NGA deployment, whereas competitive pressure from broadband and mobile affects NGA deployment in an inverted U-shaped manner. Hence, they find also empirical evidence for the above mentioned trade-off. Furthermore, they expect that the large investments required to establish a reasonable NGA roll-out will not elicit with the cost-based access regulation of the European Commission.

The trade-off is reflected in the choice between a facilities-based competition (entrants invest in their own network) and a service-based competition (incumbent must grant access to its network). Policy makers posit that facilities-based competition is more advantageous than service-based competition. For instance, they mention that facilities-based competition provides higher variety, lower long-term pricing, and more innovation whereas service-based competition would only promote lower prices that result from regulatory intervention. Höffler (2007) supports the government preference for facilities-based competition with an empirical study that provides evidence from broadband networks. He shows that infrastructure competition between Digital Subscriber Line (DSL) and cable TV had a significant positive impact on broadband penetration. The European Commission (2007) announced a position that favorably describes facilities-based competition: "empirical evidence shows that investment and innovation are strongest where there is effective competition between infrastructures. However, there is still no infrastructure-based competition on around 80% of the EU's local loops. This means that ex-ante regulation continues to play a crucial role in maintaining competition and protecting consumers by setting conditions for access to the incumbent's infrastructure." Focusing on these insights, finding incentives for infrastructure investment is a key policy issue.

Huigen and Cave (2008) compare the deregulatory approach in the United States with the regulatory approach widely adopted in the European Union. They find that investment incentives are weaker where there is only one network in which services will be provided. Focusing on the European Union territory, they analyze the prospects for competition in wireless and municipal networks and recommend that steps be taken to mobilize incentives to invest in NGA networks where competition works. If there is a lack of competition, policy makers must consider conditions to incentivize investments. Duso and Röller (2003) support a more critical point of view on deregulation. They treat deregulation across OECD countries as exogenous and explore its competitive impact on productivity which they find as significantly overestimated.

The most recent challenge in terms of regulated network access deals with the current fibre-optic roll-out in many industrialized countries. Like the copper cable network, it is likely that the fibre-optic network will be regulated in the future and prices will become mandated.[10] Then, firms that invest in a fibre-optic network today would have to grant access to their network for competitors after a certain period of time. The price would then be set ex-ante by the regulating authority. A facilities-based approach would necessarily lead to a duplication of the infrastructure whereas regulated access would undermine the

[10] The two companion papers by Laffont, Rey, and Tirole (1998a,b) provide an insightful overview to network competition and the underlying pricing rule.

investment incentive by the incumbent.[11]

Grajek and Röller (2012) employ an empirical framework that identifies the effects of access regulation while assuming that the incumbent's and entrant's investment decisions are interdependent and investment incentives are not necessarily aligned. Their setting characterizes the incumbent's and entrant's investments as substitutes or as complements.[12] In addition to indications about the regulation/investment trade-off they find a regulatory commitment problem since higher investments by incumbents encourage regulated access provisions.[13] With our extended defender model, we establish a consistent explanation for the regulation/investment trade-off and its empirical evidence provided by Grajek and Röller.

Suppose the scenario in which the incumbent's position (firm D) is at the bottom right (i.e., relatively strong fixed cost and weak variable cost) and network access is regulated. It results a service-based competition in which the entrant relies on the incumbent's network and need not bear the fixed costs to build its own network. Hence, it can focus on investments for services which base on a technology that imposes mainly variable costs. Table 3.1 shows the incumbent's reactions and reflects the regulation/investment trade-off: attacked with the entrant's high provided variable cost attribute, the incumbent will cut its investments in its network infrastructure (fixed cost attribute). Hence, the incumbent's incentive to invest and maintain its network will be weakened. This might be detrimental for both parties and the customers in the retail market as well. Table 3.1 also reveals the facilities-based competition. This scenario results if the entrant attacks with its low provided fixed cost attribute and the incumbent reacts with an increase of its investment in its network (fixed cost attribute). Therefore, network competition encourages the incumbent to increase the quality and maintenance of its network. Table 3.1 consistently proves the investment behavior in a facilities-based as well as in a service-based competition that has been addressed empirically by Grajek and Röller (2012) and Briglauer, Ecker, and Gugler (2012).

Furthermore, the incumbent competes with a lower price if there is facilities-based competition. If service-based competition takes place and the incumbent reaches a certain market share threshold, there will be competition in price as well. The incumbent's reaction to an entrant's low price strategy is ambiguous, depending on the markup-effect and on the quantity-effect.

[11]Cave (2007) illuminates the debate about the fibre-optic roll-out and the related regulation issues, describing how the European regulatory framework approaches it.

[12]Buehler and Wey (2013) work out conditions under which a state-owned firm with a political agenda strategically crowds out investment by a private firm. They apply a two step procedure to identify a possible crowding out in the telecommunications industry. Specifically, they investigate the construction of the fibre-optic network roll-out in industrialized countries. In Switzerland, for instance, they provide anecdotal evidence that the two investments are strategic complements rather than substitutes what makes a crowding out unlikely to occur.

[13]Armstrong and Sappington (2006) discuss whether and how regulators can introduce competition in regulated markets. They distinguish procompetitive and anticompetitive liberalization policies.

3.5 Conclusion

We have given the original defender model more structure by explicitly modeling the costs associated with quality attributes, showing that firms compete in three dimensions, two quality attributes and price. The two quality attributes induce fixed and variable costs. This setting allows us to derive defensive strategies in terms of industry specific market and cost structures in a tractable framework.

The defender model best explains markets in which a dominant firm operates with a technology that induces mainly fixed costs and entrants focus their activity on low cost technologies. For such markets, we derive rich insights into how incumbents and entrants should optimally behave.

We provide two applications that highlight our results. The first application analyzes the market for letter mail which has recently been opened to competition in most European countries. This has forced incumbent postal operators to (re)position themselves strategically. In this context, our results extend the literature on competition in liberalized postal markets by combining pricing and positioning strategies from a marketing perspective.

The second application focuses on the telecommunications industry in general and Next Generation Networks (e.g., fibre-optic roll-out) in particular. To the best of our knowledge, our research is unique in addressing these questions by the application of the defender model. Our model theoretically confirms the empirical evidence of the regulation/investment trade-off by Grajek and Röller (2012) and Briglauer, Ecker, and Gugler (2012). This trade-off states that access regulation might increase competition and lower prices but it might also undermine investment incentives over time.

Based on the case in which the incumbent provides technology that imposes high fixed costs, we show that the incumbent's incentive to invest in its network declines if the entrant focuses its investment on variable cost technologies. This is service-based competition. Facilities-based competition results if an entrant attacks with an investment in an own network. This encourages the incumbent to increase its investment in the network as well, resulting in better infrastructure and maintenance. Moreover, the incumbent lowers prices if a facilities-based competition takes place.

Our analysis highlights the importance of the strategic aspects of market defense. Of course, additional attributes and more detailed cost structures could enhance and also complicate the analysis. We leave these developments to future research.

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Appendix B

B.1 First Order Conditions

By analyzing the three first order conditions

$$\frac{\partial \pi_D}{\partial x} = \frac{\partial m_D}{\partial x}\left(P_D - gV_D^d\right) + m_D \frac{\partial\left(P_D - gV_D^d\right)}{\partial x} - \frac{\partial (fF_D^b)}{\partial x} = 0,$$

with $x \in \boldsymbol{\Omega_D}$, it turns out that the markup $P_D - gV_D^d$ has to be positive since the first order derivatives of firm D's market share $\partial m_D/\partial x, x \in \boldsymbol{\Omega_D}$ are positive for the derivatives with respect to the two quality attributes and negative for the derivative with respect to the price of firm D. With the relationship $m_D = 1 - m_A$ these derivatives are given as $dm_D/dx = -dm_A/dx$, $x \in \boldsymbol{\Omega_D}$, where dm_D/dx is given in equations (B.4) to (B.6).

The marginal market share of firm D with respect to firm A's quality attributes is negative whereas it is positive for its price.

$$\frac{\partial m_D}{\partial V_A} = \frac{2}{\pi} \frac{\frac{F_D}{P_D} - \frac{F_A}{P_A}}{P_A\left[\left(\frac{F_A}{P_A} - \frac{F_D}{P_D}\right)^2 + \left(\frac{V_D}{P_D} - \frac{V_A}{P_A}\right)^2\right]} < 0 \tag{B.4}$$

$$\frac{\partial m_D}{\partial F_A} = \frac{2}{\pi} \frac{\frac{V_A}{P_A} - \frac{V_D}{P_D}}{P_A\left[\left(\frac{F_A}{P_A} - \frac{F_D}{P_D}\right)^2 + \left(\frac{V_D}{P_D} - \frac{V_A}{P_A}\right)^2\right]} < 0 \tag{B.5}$$

$$\frac{\partial m_D}{\partial P_A} = \frac{2}{\pi} \frac{\left(\frac{V_D}{P_D}\frac{F_A}{P_A} - \frac{V_A}{P_A}\frac{F_D}{P_D}\right)}{P_A\left[\left(\frac{F_A}{P_A} - \frac{F_D}{P_D}\right)^2 + \left(\frac{V_D}{P_D} - \frac{V_A}{P_A}\right)^2\right]} > 0. \tag{B.6}$$

Keep this in mind for the following proofs of Proposition 3.1 to 3.3.

B.2 Second Order Conditions

The total derivatives in equation (3.1) require that $\partial^2 \pi_D/\partial x^2 < 0,\ x \in \boldsymbol{\Omega_D^*}$ to ensure a maximum at position x. In what follows we show the conditions which guarantee that this is fulfilled for the closed-form profit function in equation (3.3). Note that $\partial^2 m_D/\partial V_D^2$ is negative (positive) if firm D is positioned at the top left (bottom right) and $\partial^2 m_D/\partial F_D^2$ is positive (negative) if firm D is positioned at the top left (bottom right). Furthermore, $\partial^2 m_D/\partial P_D^2$ is ambiguous, $\partial m_D/\partial V_D > 0$, $\partial m_D/\partial F_D > 0$ and $\partial m_D/\partial P_D < 0$.

First quality attribute

The second order condition of π_D in respect to V_D is given as

$$\frac{\partial^2 \pi_D}{\partial V_D^2} = \frac{\partial^2 m_D}{\partial V_D^2}\left(P_D - gV_D^d\right) - 2\frac{\partial m_D}{\partial V_D} gdV_D^{d-1} - m_D gd(d-1)V_D^{d-2}.$$

The above second order derivative is negative at the top left of firm D. It is also negative at the bottom right of firm D, if the two negative terms on the rhs outweigh the first term.

Second quality attribute

The second order condition of π_D in respect to F_D is given as

$$\frac{\partial^2 \pi_D}{\partial F_D^2} = \frac{\partial^2 m_D}{\partial F_D^2}\left(P_D - gV_D^d\right) - f(b-1)bF_D^{b-2}.$$

The above second order derivative is negative at the bottom right of firm D. It is also negative at the top left of firm D if the second term on the rhs outweighs the first term.

Incumbent's price

The second order condition of π_D in respect to P_D results as

$$\frac{\partial^2 \pi_D}{\partial P_D^2} = \frac{\partial^2 m_D}{\partial P_D^2}\left(P_D - gV_D^d\right) + 2\frac{\partial m_D}{\partial P_D}.$$

The sum of the negative second term and the first term on the rhs has to be negative in order to obtain a maximum in equation (3.1).

B.3 Proof of Proposition 3.1

The following analysis assumes Firm D to be positioned at the top left of firm A. If firm D is positioned at the bottom right instead, the quantity-effect will change its sign.

Attacked on $\mathbf{V_D}$: We find the reaction of firm D by analyzing the mixed second order derivative

$$\frac{\partial^2 \pi_D}{\partial V_D \partial V_A} = \frac{\partial^2 m_D}{\partial V_D \partial V_A}\left(P_D - gV_D^d\right) - gdV_D^{d-1}\frac{\partial m_D}{\partial V_A}.$$

The markup-effect is positive (see equation B.4) whereas the sign of the quantity-effect corresponds to

$$\frac{\partial^2 m_D}{\partial V_D \partial V_A} = \frac{2}{\pi}\frac{2\left(\frac{V_D}{P_D} - \frac{V_A}{P_A}\right)\left(\frac{F_A}{P_A} - \frac{F_D}{P_D}\right)}{P_D P_A\left[\left(\frac{F_A}{P_A} - \frac{F_D}{P_D}\right)^2 + \left(\frac{V_D}{P_D} - \frac{V_A}{P_A}\right)^2\right]^2} > 0.$$

This completes the proof of an attack on firm D's variable cost attribute in Proposition 3.1.

Attacked on $\mathbf{F_D}$: We find the reaction of firm D by analyzing the mixed second order derivative

$$\frac{\partial^2 \pi_D}{\partial F_D \partial V_A} = \frac{\partial^2 m_D}{\partial F_D \partial V_A} \left(P_D - g V_D^d\right).$$

The markup-effect vanishes since fixed costs do not rely on the quantity and the sign of the quantity-effect corresponds to

$$\frac{\partial^2 m_D}{\partial F_D \partial V_A} = \frac{2}{\pi} \frac{\left(\frac{V_D}{P_D} - \frac{V_A}{P_A}\right)^2 - \left(\frac{F_A}{P_A} - \frac{F_D}{P_D}\right)^2}{P_D P_A \left[\left(\frac{F_A}{P_A} - \frac{F_D}{P_D}\right)^2 + \left(\frac{V_D}{P_D} - \frac{V_A}{P_A}\right)^2\right]^2} \gtreqless 0.$$

Straightforward calculations yield

$$\frac{\partial^2 m_D}{\partial F_D \partial V_A} \gtreqless 0 \;\Leftrightarrow\; m_D = \frac{2}{\pi} \arctan\left(\frac{\frac{V_D}{P_D} - \frac{V_A}{P_A}}{\frac{F_A}{P_A} - \frac{F_D}{P_D}}\right) \gtreqless \frac{1}{2}.$$

Proposition 3.1 follows then immediately.

Attacked on $\mathbf{P_D}$: We find the reaction of firm D by analyzing the mixed second order derivative

$$\frac{\partial^2 \pi_D}{\partial P_D \partial V_A} = \frac{\partial^2 m_D}{\partial P_D \partial V_A} \left(P_D - g V_D^d\right) + \frac{\partial m_D}{\partial V_A}.$$

Equation (B.6) states that the markup-effect is negative. The quantity-effect is given as

$$\frac{\partial^2 m_D}{\partial P_D \partial V_A} = \frac{2}{\pi} \frac{\frac{F_D}{P_D}\left[\left(\frac{F_D}{P_D} - \frac{F_A}{P_A}\right)^2 + \left(\frac{V_D^2}{P_D^2} - \frac{V_A^2}{P_A^2}\right)\right] - 2\frac{V_D}{P_D}\frac{F_A}{P_A}\left(\frac{V_D}{P_D} - \frac{V_A}{P_A}\right)}{P_D P_A \left[\left(\frac{F_A}{P_A} - \frac{F_D}{P_D}\right)^2 + \left(\frac{V_D}{P_D} - \frac{V_A}{P_A}\right)^2\right]^2}.$$

For the proof we define $x_i \equiv V_i/P_i,\ y_i \equiv F_i/P_i$ with $i \in \{D, A\}$ and assume $x_D - x_A \geqslant y_A - y_D > 0$ (corresponds to a market share $m_D \geqslant m_A$). Then, we derive the condition

$$y_D \left[(y_A - y_D)^2 - (x_D - x_A)\left(\left(2\frac{y_A}{y_D} - 1\right) x_D - x_A\right)\right] < 0.$$

This holds true because $(2y_A/y_D - 1)\, x_D - x_A > x_D - x_A \geqslant y_A - y_D > 0$. Therefore, given $m_D \geqslant m_A$ it is $\partial^2 m_D/(\partial P_D \partial V_A) < 0$. For $m_A > m_D$ the derivative may become positive above a certain threshold $m_A \geqslant \tilde{m}_{P,V}$.

This proves the reaction of firm D if attacked on its price.

B.4 Proof of Proposition 3.2

The following analysis assumes Firm D to be positioned at the top left of firm A. If firm D is positioned at the bottom right instead, the quantity-effect will change its sign.

Attacked on $\mathbf{V_D}$: We find the reaction of firm D by analyzing the mixed second order derivative

$$\frac{\partial^2 \pi_D}{\partial V_D \partial F_A} = \frac{\partial^2 m_D}{\partial V_D \partial F_A} \left(P_D - gV_D^d\right) - gdV_D^{d-1} \frac{\partial m_D}{\partial F_A}.$$

Equation (B.5) proves that the markup-effect is positive. The quantity-effect corresponds to

$$\frac{\partial^2 m_D}{\partial V_D \partial F_A} = \frac{2}{\pi} \frac{\left(\frac{V_D}{P_D} - \frac{V_A}{P_A}\right)^2 - \left(\frac{F_A}{P_A} - \frac{F_D}{P_D}\right)^2}{P_D P_A \left[\left(\frac{F_A}{P_A} - \frac{F_D}{P_D}\right)^2 + \left(\frac{V_D}{P_D} - \frac{V_A}{P_A}\right)^2\right]^2} \gtreqless 0.$$

Straightforward calculations yield

$$\frac{\partial^2 m_D}{\partial V_D \partial F_A} \gtreqless 0 \Leftrightarrow m_D = \frac{2}{\pi} \arctan\left(\frac{\frac{V_D}{P_D} - \frac{V_A}{P_A}}{\frac{F_A}{P_A} - \frac{F_D}{P_D}}\right) \gtreqless \frac{1}{2}.$$

It follows the reaction of firm D if attacked on its variable cost attribute.

Attacked on $\mathbf{F_D}$: We find the reaction of firm D by analyzing the mixed second order derivative

$$\frac{\partial^2 \pi_D}{\partial F_D \partial F_A} = \frac{\partial^2 m_D}{\partial F_D \partial F_A} \left(P_D - gV_D^d\right).$$

The markup-effect vanishes since fixed costs do not rely on quantity. The quantity-effect corresponds to

$$\frac{\partial^2 m_D}{\partial F_D \partial F_A} = \frac{2\left(\frac{V_A}{P_A} - \frac{V_D}{P_D}\right)\left(\frac{F_A}{P_A} - \frac{F_D}{P_D}\right)}{P_D P_A \left[\left(\frac{F_A}{P_A} - \frac{F_D}{P_D}\right)^2 + \left(\frac{V_D}{P_D} - \frac{V_A}{P_A}\right)^2\right]^2} < 0.$$

This completes the proof of firm D's reaction if attacked on its fixed cost attribute.

Attacked on $\mathbf{P_D}$: We find the reaction of firm D by analyzing the mixed second order derivative

$$\frac{\partial^2 \pi_D}{\partial P_D \partial F_A} = \frac{\partial^2 m_D}{\partial P_D \partial F_A} \left(P_D - gV_D^d\right) + \frac{\partial m_D}{\partial F_A}.$$

Equation (B.5) proves that the markup-effect is negative. The quantity-effect denotes as

$$\frac{\partial^2 m_D}{\partial P_D \partial F_A} = -\frac{2}{\pi} \frac{\frac{V_D}{P_D}\left[\left(\frac{V_D}{P_D} - \frac{V_A}{P_A}\right)^2 - \left(\frac{F_A^2}{P_A^2} - \frac{F_D^2}{P_D^2}\right)\right] + 2\frac{V_A}{P_A}\frac{F_D}{P_D}\left(\frac{F_A}{P_A} - \frac{F_D}{P_D}\right)}{P_D P_A \left[\left(\frac{F_A}{P_A} - \frac{F_D}{P_D}\right)^2 + \left(\frac{V_D}{P_D} - \frac{V_A}{P_A}\right)^2\right]^2}.$$

Again, we define $x_i \equiv V_i/P_i,\ y_i \equiv F_i/P_i$ with $i \in \{D, A\}$ and assume $y_A - y_D \geqslant x_D - x_A > 0$ (corresponds to a market share $m_A \geqslant m_D$). Then, we derive the condition

$$-x_D \left[(x_D - x_A)^2 - (y_A - y_D)\left(y_A + \left(1 + 2\frac{x_A}{x_D}\right) y_D\right)\right] > 0.$$

This is given since $y_A + (1 + 2x_A/x_D)\, y_D > y_A - y_D \geqslant x_D - x_A$. Therefore, given $m_A \geqslant m_D$ it is $\partial^2 m_D/(\partial P_D \partial F_A) > 0$. For $m_D > m_A$ the derivative may become negative above a certain threshold $m_D \geqslant \tilde{m}_{P,F}$.

This proves the reaction of firm D if attacked on its price.

B.5 Proof of Proposition 3.3

The following analysis assumes Firm D to be positioned at the top left of firm A. If firm D is positioned at the bottom right instead, the quantity-effect will change its sign.

Attacked on $\mathbf{V_D}$: We find the reaction of firm D by analyzing the mixed second order derivative

$$\frac{\partial^2 \pi_D}{\partial V_D \partial P_A} = \frac{\partial^2 m_D}{\partial V_D \partial P_A}\left(P_D - g V_D^d\right) - g d V_D^{d-1} \frac{\partial m_D}{\partial P_A}.$$

Equation (B.6) proves the negative markup-effect. The quantity-effect results as

$$\frac{\partial^2 m_D}{\partial V_D \partial P_A} = \frac{2}{\pi} \frac{\frac{F_A}{P_A}\left[\left(\frac{F_A}{P_A} - \frac{F_D}{P_D}\right)^2 - \left(\frac{V_D^2}{P_D^2} - \frac{V_A^2}{P_A^2}\right)\right] + 2\frac{V_A}{P_A}\frac{F_D}{P_D}\left(\frac{V_D}{P_D} - \frac{V_A}{P_A}\right)}{P_D P_A \left[\left(\frac{F_A}{P_A} - \frac{F_D}{P_D}\right)^2 + \left(\frac{V_D}{P_D} - \frac{V_A}{P_A}\right)^2\right]^2}.$$

To prove the sign of this mixed derivative, we define $x_i \equiv V_i/P_i,\ y_i \equiv F_i/P_i$ with $i \in \{D, A\}$ and assume $x_D - x_A \geqslant y_A - y_D > 0$ (corresponds to a market share $m_D \geqslant m_A$). By reformulating the nominator to

$$y_A \left[(y_A - y_D)^2 - (x_D - x_A)\left(x_D - \left(2\frac{y_D}{y_A} - 1\right) x_A\right)\right] < 0$$

we see that it is always negative. This follows since $x_D - (2y_D/y_A - 1)x_A > x_D - x_A \geqslant y_A - y_D$. Therefore, given $m_D \geqslant m_A$ it is $\partial^2 m_D/(\partial V_D \partial P_A) < 0$. For $m_A > m_D$ the derivative may become positive above a certain threshold $m_A \geqslant \tilde{m}_{V,P}$.

This completes the proof of an attack on firm D's variable cost attribute.

Attacked on $\mathbf{F_D}$: We find the reaction of firm D by analyzing the mixed second order derivative

$$\frac{\partial^2 \pi_D}{\partial F_D \partial P_A} = \frac{\partial^2 m_D}{\partial F_D \partial P_A}\left(P_D - gV_D^d\right).$$

The markup-effect vanishes since fixed costs do not rely on the provided quantity. Therefore, the quantity-effect denotes as:

$$\frac{\partial^2 m_D}{\partial F_D \partial P_A} = -\frac{2}{\pi}\frac{\frac{V_A}{P_A}\left[\left(\frac{V_A}{P_A}-\frac{V_D}{P_D}\right)^2-\left(\frac{F_D^2}{P_D^2}-\frac{F_A^2}{P_A^2}\right)\right]+2\frac{V_D}{P_D}\frac{F_A}{P_A}\left(\frac{F_D}{P_D}-\frac{F_A}{P_A}\right)}{P_D P_A\left[\left(\frac{F_A}{P_A}-\frac{F_D}{P_D}\right)^2+\left(\frac{V_D}{P_D}-\frac{V_A}{P_A}\right)^2\right]^2}.$$

We define $x_i \equiv V_i/P_i,\ y_i \equiv F_i/P_i$ with $i \in \{D, A\}$ and assume $y_A - y_D \geqslant x_D - x_A > 0$ (corresponds to a market share $m_A \geqslant m_D$). By reformulating the nominator to

$$-x_A\left[(x_D - x_A)^2 - (y_A - y_D)\left(\left(2\frac{x_D}{x_A}-1\right)y_A - y_D\right)\right] > 0$$

we see that it is always negative since $(2x_D/x_A - 1)\, y_A - y_D > y_A - y_D \geqslant x_D - x_A$. Therefore, given $m_A \geqslant m_D$ it is $\partial^2 m_D/(\partial F_D \partial P_A) > 0$. For $m_D > m_A$ the derivative may become negative above a certain threshold $m_D \geqslant \tilde{m}_{F,P}$.

This proves the reaction by firm D if attacked on its fixed cost attribute.

Attacked on $\mathbf{P_D}$: We find the reaction of firm D by analyzing the mixed second order derivative

$$\frac{\partial^2 \pi_D}{\partial P_D \partial P_A} = \frac{\partial^2 m_D}{\partial P_D \partial P_A}\left(P_D - gV_D^d\right) + \frac{\partial m_D}{\partial P_A}.$$

Equation (B.6) proves that the markup-effect is positive. The quantity-effect is given as

$$\frac{\partial^2 m_D}{\partial P_D \partial P_A} = \frac{2}{\pi}\frac{\left(\frac{V_D}{P_D}\frac{F_A}{P_A}-\frac{V_A}{P_A}\frac{F_D}{P_D}\right)\left[\left(\frac{V_D^2}{P_D^2}+\frac{F_D^2}{P_D^2}\right)-\left(\frac{V_A^2}{P_A^2}+\frac{F_A^2}{P_A^2}\right)\right]}{P_D P_A\left[\left(\frac{F_A}{P_A}-\frac{F_D}{P_D}\right)^2+\left(\frac{V_D}{P_D}-\frac{V_A}{P_A}\right)^2\right]^2} \gtreqless 0.$$

The expression in nominator's first bracket is positive.

Again, we define $x_i \equiv V_i/P_i$ and $y_i \equiv F_i/P_i$ with $i \in \{D, A\}$. Then, the expression in nominator's second bracket can be written as

$$m_D \gtreqless \frac{2}{\pi}\arctan\left(\frac{y_D + y_A}{x_D + x_A}\right) = \tilde{m}_{P,P} \quad \Leftrightarrow \quad \frac{\partial^2 m_D}{\partial P_D \partial P_A} \gtreqless 0.$$

This proves the reaction of firm D if attacked on its price.

B.6 Proof of Lemma 3.3

We already now that the relationship $m_D = 1 - m_A$ holds. Furthermore, the *Schwarz Theorem* states that if $f : \mathbb{R}^n \rightarrow \mathbb{R}$ has continuous second partial derivatives at any given point $\mathbb{R}^n$, say, $(a_1, \ldots, a_n)$, then for $1 \leq i,\ j \leq n$,

$$\frac{\partial^2 f}{\partial x_i \partial x_j}(a_1, \ldots, a_n) \quad = \quad \frac{\partial^2 f}{\partial x_j \partial x_i}(a_1, \ldots, a_n).$$

Based on this theorem we can formulate the following two relationships:

$$\begin{aligned} \frac{\partial m_j}{\partial x} &= -\frac{\partial m_i}{\partial x} \\ \frac{\partial^2 m_j}{\partial y \partial x} &= -\frac{\partial^2 m_i}{\partial x \partial y}, \end{aligned}$$

where $i, j \in \{D, A\},\ \ x \in \boldsymbol{\Omega_D}$ and $y \in \boldsymbol{\Omega_A}$. This proves Lemma 3.3.

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